UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

SEP 26 2017

REPLY TO THE ATTENTION OF:
WW-16J

Diana Klemans, Chief
Surface Water Assessment Section, Water Resources Division
Michigan Department of Environmental Quality
525 West Allegan Street
P.O. BOX 30473
Lansing, Michigan 48909-7973

Dear Ms. Klemans:

The U.S. Environmental Protection Agency has conducted a complete review of the final State-wide Total Maximum Daily Loads (TMDLs) for Polychlorinated Biphenyls (PCBs), including supporting documentation and follow up information. This TMDL report addresses PCB-impaired waters across the State of Michigan. The TMDL report submitted by the Michigan Department of Environmental Quality addresses waterbodies impaired by PCBs in fish tissue or the water column.

The TMDLs meet the requirements of Section 303(d) of the Clean Water Act and EPA's implementing regulations at 40 C.F.R. Part 130. Therefore, EPA hereby approves Michigan's 2104 TMDLs for PCBs as noted in Appendix A of the enclosed decision document. The statutory and regulatory requirements, and EPA' s review of Michigan's compliance with each requirement, are described in the enclosed decision document.

We wish to acknowledge Michigan's effort in submitting these TMDLs and look forward to future TMDL submissions by the State of Michigan. If you have any questions, please contact Mr. Peter Swenson, Chief of the Watersheds and Wetlands Branch, at 312-886-0236.

Sincerely,

Christopher Korleski
Director, Water Division

Enclosure

cc: Gary Kohlhepp, MDEQ

TMDL: Statewide PCB TMDL, Michigan
Effective Date: 9/26/2017

Decision Document for Approval of The Michigan Statewide PCB TMDL Report

Section 303(d) of the Clean Water Act (CWA) and EPA's implementing regulations at 40 C.F.R. Part 130 describe the statutory and regulatory requirements for approvable TMDLs. EPA's TMDL review guidelines are not themselves regulations. They are an attempt to summarize and provide guidance regarding currently effective statutory and regulatory requirements relating to TMDLs. Any differences between these guidelines and EPA's TMDL regulations should be resolved in favor of the regulations themselves. Additional information is generally necessary for EPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations, and should be included in the submittal package. Use of the verb "must" below denotes information that is required to be submitted because it relates to elements of the TMDL required by the CWA and by regulation. Use of the term "should" below denotes information that is generally necessary for EPA to determine if a submitted TMDL is approvable.

1. Identification of Waterbody, Pollutant of Concern, Pollutant Sources, and Priority Ranking

EPA's review guidelines state that the TMDL submittal should identify the waterbody as it appears on the State's/Tribe's 303(d) list. The waterbody should be identified/georeferenced using the National Hydrography Dataset (NHD), and the TMDL should clearly identify the pollutant for which the TMDL is being established. In addition, the TMDL should identify the priority ranking of the waterbody and specify the link between the pollutant of concern and the water quality standard (see Section 2 below).

The TMDL submittal should include an identification of the point and non-point sources of the pollutant of concern, including location of the source(s) and the quantity of the loading, e.g., lbs/per day. The TMDL should provide the identification numbers of the NPDES permits within the waterbody. Where it is possible to separate natural background from non-point sources, the TMDL should include a description of the natural background. This information is necessary for EPA's review of the load and wasteload allocations, which are required by regulation.

The TMDL submittal should also contain a description of any important assumptions made in developing the TMDL, such as:

(1) the spatial extent of the watershed in which the impaired waterbody is located;
(2) the assumed distribution of land use in the watershed (e.g., urban, forested, agriculture);
(3) population characteristics, wildlife resources, and other relevant information affecting the characterization of the pollutant of concern and its allocation to sources;
(4) present and future growth trends, if taken into consideration in preparing the TMDL (e.g., the TMDL could include the design capacity of a wastewater treatment facility); and

(5) an explanation and analytical basis for expressing the TMDL through *surrogate measures*, if applicable.

Comment:
Introduction

Michigan has identified 2,255 inland water Assessment Unit Identifiers (AUIDs) as impaired due to polychlorinated biphenyls (PCBs), based on fish tissue and water column data. Because these AUIDs are impaired by a pollutant, they require a TMDL. Typically, a TMDL is developed for a given waterbody-pollutant combination, and its loads are expressed as mass per unit of time calculations set at a level to implement applicable water quality standards. This PCB TMDL is different from traditional TMDLs in two respects. First, this PCB TMDL developed by Michigan was calculated on a state-wide scale, rather than a waterbody or watershed scale. Michigan is about 96,716 square miles in area and over 50,000 miles of stream and 145,000 acres of lakes are listed as impaired for PCBs (Section 1.0 of the TMDL). In addition, Michigan has over 7,000 lakes greater than 10 acres in size, so this TMDL is much larger in scale than most waterbody/watershed TMDLs. Second, this TMDL's PCB target is expressed in terms of PCB concentration rather than mass per unit of time. EPA finds Michigan's state-wide approach reasonable because many of Michigan's waters identified as impaired due to PCBs and all of the waters covered by this TMDL, with the exception of those discussed in Section 5 of this Decision Document, *NPDES Individual Facility Permits*, have no known source of PCBs, other than air deposition.

After considering research, which is presented in detail in the TMDL and discussed further in this Decision Document under the *Problem Definition* and *Overview of Sources* sections, Michigan determined that the dominant source of PCB loadings statewide is air deposition (Section 5.2 of the TMDL). Based on this finding, and because the loadings from air deposition are distributed across waterbodies in the state, Michigan developed the TMDL on a statewide basis, rather than for individual water bodies.

In addition, because air deposition is the predominant source of PCB loadings, Michigan chose to calculate the TMDL assuming a proportional relationship between air deposition and fish tissue PCB concentrations. To calculate the load reductions needed to meet water quality standards, the state assumed that reductions in air loadings would result in a proportional reduction in fish tissue PCB concentrations (Section 3.2 of the TMDL). Michigan found few studies and data to support a mass-based loading target, but found that data supported a concentration-based target. Michigan used PCB concentrations[1] in air to describe the PCB (source) reductions needed, and a fish tissue concentration target to represent the assimilative capacity of Michigan waterbodies (Sections 3.3 and 3.5 of this Decision Document).

MDEQ's approach is built around air as the dominant PCB source, using available Great Lakes data and research as described further in the Decision Document, and taking into account the specific characteristics of the pollutant (i.e., PCBs) and the geographical characteristics of the Great Lakes Region and Michigan. These are discussed below:

1. Many inland waters in Michigan lack specific data to characterize the highly diffuse, and limited direct sources of PCBs to waterbodies throughout the state. In contrast, a significant amount of data and research describing the behavior of PCBs in the

1 At steady state conditions.

atmospheric environment has been generated for the Great Lakes, utilizing data from the Great Lakes Air Deposition Network (IADN). These data are of a scale, duration, quality, and quantity to support a Statewide Air Deposition PCB TMDL. See Section 4.1 of the TMDL.

2. PCBs are hydrophobic, which causes them to behave differently in the environment than most TMDL pollutants. Gas phase PCBs absorb into the waters' surface, rather than "deposit" onto the water surface, a different physical mechanism than most pollutants.

3. Great Lakes and other research shows that at least 90% of total air deposition of PCBs to the lakes is in the form of gaseous PCB absorption into the Great Lakes surface (in addition to wet and dry deposition which contribute less than 10%).[2]

4. A number of physical characteristics specific to the Great Lakes exert a significant influence on the State. The Great Lakes surround the State of Michigan, and conditions affecting PCBs within the Great Lakes system are unique. The combined surface area of the Great Lakes is 94,250 square miles providing a large scale interface for gas phase PCBs to absorb into the waters' surface. PCBs absorbed into the lakes can remain for many years, and can also be transported through the lakes due to the slow movement of water through the lakes (for example, taking 99 years to travel through Lake Michigan alone).[3] PCBs can re-volatilize and, according to the Agency for Toxic Substances and Disease Registry, can travel long distances in the air and have been found in snow and water far away from where they were released, contributing to the regional PCB background concentration (explained further in Section 4.3 of the TMDL).[4]

While most of the PCB-listed inland waterbodies in Michigan have characteristics that are compatible with the assumptions of the approach used in this PCB TMDL, waters were specifically excluded from the TMDL where they had known legacy PCB sources, such as Superfund sites; or where the reduction in atmospheric concentration alone was not expected to meet the target PCB fish tissue concentration. A number of waters in the latter category are located in the vicinity of PCB Superfund sites or highly industrialized areas; others may have unidentified non-air PCB sources making the assumptions used in the TMDL potentially invalid. PCB sources, pathways, and the biological mechanisms affecting the behavior of PCBs in these excluded waters will need to be addressed in future TMDLs following additional study to determine appropriate strategies to address the PCB impairment.

As discussed in the following Decision Document, EPA finds Michigan's statewide, air deposition-based approach to be reasonable for waters where the assumptions and conditions of the TMDL approach used are applicable. Where these assumptions do not apply, for example, where air is not the primary source of PCBs and where there may be other sources such as legacy sources, Michigan has appropriately omitted those waters from this TMDL, and will develop separate TMDLs for these waters. EPA also finds that the use of PCB air concentrations to estimate loadings, and the proportional relationship between PCB air concentration and fish tissue concentration, are reasonable.

---

2 According to Mandalakis, 2006 "...the predominance of gaseous PCBs in the atmosphere is well-known and it has been pointed out in several other studies..."

3 https://www.statista.com/statistics/204184/retention-replacement-time-of-the-largest-lakes-in-the-us/ accessed 11/1/16.

4 ATSDR Toxic Substances Portal, 2001.

TMDL Location and Scope

On August 29, 2013, the Michigan Department of Environmental Quality (MDEQ) submitted a TMDL report to address waterbodies impaired due to polychlorinated biphenyls (PCBs). The scope of this PCB TMDL covers inland water bodies in the state of Michigan that are impaired by PCBs whose primary source is atmospheric deposition. For purposes of this TMDL, inland water bodies are any segments that are not part of the Great Lakes or connecting channels (i.e., Lake St. Clair, the St. Clair River, the St. Mary's River, the Detroit River, and the Keweenaw waterway) (Section 2.3 of the TMDL). Based on the existing and available data and information, Michigan has determined that the primary PCB pathway is likely to be air deposition in the waters addressed by this TMDL. Because there are a large number of PCB-impaired waters in the State whose primary pathway is air deposition, Michigan developed the TMDL on a state-wide basis, encompassing all inland waters of the State which have characteristics that are consistent with the definitional scope of the TMDL, as outlined in Section 2.3 of the TMDL.

Problem Definition

PCBs are a class of synthetic, chlorinated organic chemicals that were produced and used because of their insulating and stable properties prior to being banned in 1978. It is estimated that over half of the U.S. production of PCBs occurred between 1960 and 1974. Many technical mixtures and different trade names were used throughout the production period (e.g., Aroclor, Askarel, Inerteen, etc.). PCBs are known to have a variety of health effects on humans and wildlife including cancer effects to the nervous, immune, reproductive and endocrine systems (Section 2.1 of the TMDL). PCBs are ubiquitous throughout the environment in the State of Michigan due to the way that they interact with and cycle throughout the environment.

An Assessment Unit Identification (AUID) unique identifier is used by the State of Michigan for each of its waters. The MDEQ identified the following inland waters in the 2012 Section 303(d) Report:

- 102 AUIDs are impaired due to PCBs in fish tissue only,
- 1,164 AUIDs are impaired due to exceedances of the ambient water quality standard (WQS) for PCBs in the water column only, and
- 989 AUIDs are impaired due to PCBs in both the water column and fish tissue.

In total, 2,255 AUIDs for inland waters are determined to be impaired due to PCBs in the State of Michigan (Section 2.2 of the TMDL). The list of water bodies submitted for approval under this TMDL (2,104 AUIDs whose primary PCB pathway is air deposition) is included in Appendix A of this Decision Document. The submittal describes the approach that Michigan has taken to develop a statewide TMDL for PCBs for waterbodies whose primary PCB pathway is air deposition. All of the waters included in this TMDL and identified in Appendix A are expected to meet WQS after the reductions in loading called for in this TMDL are achieved.

Several Michigan inland waterbodies are primarily impaired by PCBs through a process other than air deposition. These waters are primarily impaired due to historical industrial discharge or an unknown source. These waters are identified in Figure 10 of the TMDL, and include Areas of Concern (AOCs), Superfund sites, etc. Since the primary PCB pathway for these waters is not air deposition, they were excluded from this TMDL. These sites are currently being addressed by

other State or Federal programs, and the State will consider these inland water AUIDs for waterbody-specific TMDL development or pursue delisting as appropriate at a future date.

Several other PCB-impaired waters are also not covered by this TMDL and thus are not included in Appendix A of this decision document. These are waters where the PCB reductions necessary to attain WQS exceed the reductions calculated in this TMDL to attain WQS, and therefore the reductions identified in this TMDL will not be sufficient to attain WQSs (Limnotech, 2013). These waters are excluded from this TMDL, and will have separate, waterbody-specific TMDLs developed at a future date (Section 2.3 of the TMDL).

Overview of Sources

To identify the current sources of PCBs to Michigan's inland water bodies, MDEQ compiled all readily available information describing point sources (National Pollutant Discharge Elimination System (NPDES) permitted municipal, industrial, and stormwater dischargers, and runoff from Superfund and other contaminated sites), and nonpoint sources (e.g., atmospheric deposition). PCB data spanned the period from 1980 to 2011. PCB data coverage varied spatially and by media. Fish tissue data were obtained for the period 1980 to 2009, water quality data were obtained for the period 1998 to 2003, air quality data were obtained for the period 1990 to 2007, and sediment quality data were available for the period 2000 to 2002. In addition to environmental data, geographic datasets were also obtained to understand the spatial variation in PCB impairment, and other relevant contributing factors such as land cover (Table 7 of the TMDL). These data were used to estimate the current point and nonpoint source loadings of PCBs.

PCBs have no natural sources. Prior to being banned in the United States, PCBs were primarily used for closed system and heat transfer fluids (transformers, capacitors, fluorescent light ballasts, etc.; 60 percent), plasticizers (25 percent), hydraulic fluids and lubricants (10 percent), and other uses (5 percent). A major use for PCBs in Michigan was in the production of recycled carbonless copy paper. Aroclor, a PCB mixture that is one of the most commonly known trade names for PCB mixtures, was a solvent used by paper manufacturers in the Great Lakes region (Section 2.1 of the TMDL).

MDEQ identifies out-of-state sources as being accountable for 55 percent of the current gas phase concentration (air deposition) load. Michigan used relationships between wilderness populations (defined by Mittermeier, 2003) and atmospheric gas phase PCB concentration as predicted by Venier and Hites (2010) to estimate the amount of PCBs coming from out of state. Michigan used Ecological Drainage Units (EDUs) to divide the state into areas with similar characteristics such as similar gas phase PCB concentrations. EDUs define areas with similar biotic and abiotic characteristics, and generally range in size from 1,000 to 10,000 km^2. The EDU boundaries align with but are not necessarily true watershed boundaries (Higgins *et al.*, 2005). An estimate of gas phase PCB concentrations was made for each of 13 ecological drainage areas/units (EDUs) within the State (based upon Vernier and Hites, 2010), and an area-weighted average was used to determine a statewide average atmospheric gas vapor phase PCB concentration. PCB contribution due to in-state air deposition sources was defined as the difference between the total gas phase PCB concentration and the concentration in each EDU attributed to out-of-state sources. The state calculated the total atmospheric gas phase PCB concentration to be 0.115 ng/m^3, with 0.051 ng/m^2 or 45% from in-state sources. Sections 4.3

and 6.1 of the TMDL Document contain more detail on developing the in-state vs. out-of-state air deposition contribution values.

Point Sources

There are 4 Michigan point sources that discharge to an inland water body that have NPDES permits containing water quality-based effluent limits (WQBELs) for PCBs, and 5 Michigan sources that discharge to an inland water body that have substantive requirement documents (SRD)[5] with PCB discharge limits. These facilities are listed in Table 1 of this Decision Document (Table 10, Section 6.2 of the TMDL Document).

Table 1: PCB Point Source Loads

Designated Name	Permit No. or SRD No.	Authorized Flow (MGD)	Load (lbs/day)
G and H LF PRP Group	MIU990012	0.558	1.21E-07
GM - Pontiac SW Facility	MI0058908	1.44	3.10E-07
GM-Powertrain Flint North	MI0001597	0.022	4.80E-09
Liquid Disposal Inc-SF Site	MIU990003	0.05	1.10E-08
Organic Chemicals-SF Site	MIU990002	0.3	5.00E-08
Rose Twp Settling Defendant-SF	MIU990014	0.65	1.10E-07
Saginaw Twp-Center Rd LF	MI0054739	0.024	5.20E-09
U.S. EPA-Shiawassee River SF	MIU990023	0.013	2.80E-09
Wayne Disposal Inc LF	MI0056413	4	8.70E-07

While stormwater discharges are also regulated under the NPDES Municipal Separate Storm Sewer System (MS4) program (i.e., Phase I and Phase II communities), MDEQ noted that there are insufficient data regarding NPDES regulated stormwater discharges to estimate PCB loadings for specific outfalls (Section 5.2.3 in the TMDL Document).

In developing this TMDL, MDEQ treated airborne PCBs deposited to surfaces and transported to waterbodies in stormwater as air deposition sources, to be addressed by reductions of PCBs concentrations in the air. As discussed in the Introduction to this Decision Document (Section 1), MDEQ and EPA reviewed numerous PCB studies in the Great Lakes area (including Buehler and Hites, 2002, and Blanchard *et al.*, 2008) and determined that the data showed that PCBs enter Michigan waterbodies primarily through absorption from the atmosphere, or in a much more limited amount, through wet deposition (where PCBs in the atmosphere are "washed out" during rain events) or through dry deposition (where particles settle out of the atmosphere directly into the waterbody), and transported in surface runoff into waterbodies across the state. Under either process, the atmospheric concentration and related air deposition is the primary pathway for PCB introduction to Michigan waterbodies, and this TMDL was developed to address this source of PCBs. EPA notes that there may be situations where stormwater may collect PCBs through other mechanisms, such as runoff from contaminated sites, or localized particulate (dry) deposition. This TMDL does not address these situations, and the State will address these situations through individual TMDLs or other appropriate mechanisms. EPA reviewed reports from the City of Spokane, Washington (City of Spokane Integrated Clean

5 Further information on Substantive Requirement Documents is provided in Section 5 of the Decision Document.

Water Plan, 2014, and the 2014 Spokane Adaptive Management Plan), which discussed PCBs transported in stormwater. Assuming that the stormwater PCB levels throughout Michigan are similar to the higher end of a range of values of PCB amounts in Spokane stormwater, Michigan stormwater would be at least an order of magnitude below the air deposition loads in this TMDL. Spokane is more urbanized than most of Michigan, and EPA concludes that the difference would be even greater in these less-urbanized areas. EPA also notes that the State has excluded from the TMDL the waters with fish tissue concentrations exceeding the fish tissue targets. As discussed in the introduction to this Decision Document, this exclusion is sufficient to ensure that waters with unidentified sources that do not meet the assumption of air as the dominant PCB source are excluded from the TMDL, and will need to be addressed through future TMDLs or other means. Further, as noted above, this Michigan state-wide TMDL is based on information available to Michigan at the time of developing the TMDL. The science and understanding of PCBs in the environment is evolving. As information regarding additional non-air deposition sources becomes available, the TMDL may be revised, as appropriate.

Diffuse or Nonpoint Sources

For the purposes of the TMDL, MDEQ and its contractors in development of the TMDL considered air sources to be the major pathway for loadings of PCBs to surface waters, based upon an extensive review of studies in the Great Lakes region (Section 5.1.1 of the TMDL). As indicated above, limited PCB water point source data indicate PCB loadings from point sources are orders of magnitude less than air sources estimated using measured atmospheric gas phase vapor concentrations (City of Spokane Integrated Clean Water Plan, 2014; Wethington and Hornbuckle, 2005; among others). MDEQ has documented in the TMDL submittal documents that the bulk of releases of PCBs into the environment occur through air deposition sources as defined by MDEQ (Section 5 of the TMDL and Section 3 of this Decision Document).

Although production of PCBs has been banned, several legacy source types may still exist and could contribute PCBs to the environment. For example, PCBs could be introduced to water bodies through runoff from unregulated or illegal landfills and scrap yards, and leaks or explosions of electrical equipment and other equipment that still contain PCBs. Michigan did not have information regarding these potential legacy source types to support development of allocations for these potential sources. In such cases EPA interprets this to be equivalent to an allocation of zero. In Section 7 of the TMDL, MDEQ describes several programs in place to address these legacy sources as they are discovered. Michigan's finding is based upon data available at the time the TMDL was written and TMDLs amendments may occur based on new information.

Smokestacks are also sources of PCBs for the air deposition when PCBs are released through combustion. There are several Michigan facilities with permits under the Clean Air Act that are authorized to release PCBs into the air (Table 6 of the TMDL Document). The total loadings of PCBs to the atmosphere from these permitted facilities were estimated to be about 1.06 lbs/year.

Prioritization

Considerations used to prioritize TMDL development in Michigan include the existing TMDL schedule (i.e., the number of TMDLs currently scheduled for each year), Michigan's five-year rotating watershed monitoring cycle, available staff and monetary resources to complete TMDLs, data and supporting information on quality and quantity of the pollutant causing the

impairment, complexity of the problem and severity of the pollution, and EPA's recommendation to develop TMDLs within 13 years of listing. A scheduled completion date for TMDLs to address PCB impairment of inland water bodies was proposed for 2013 in the Michigan 2012 Integrated Report (Section 2.1 of the TMDL).

EPA has reviewed the relevant parts of the submitted TMDL and, for the reasons discussed in this section of the decision document, finds that the TMDL document adequately identifies the impaired water bodies, pollutant of concern, and pollutant sources that are addressed by this TMDL. EPA finds that the State compiled and reviewed all readily available information including but not limited to NPDES data, air discharge data, and fish tissue data, to identify the sources of PCBs addressed in this TMDL. EPA also finds that the State adequately defined how various key terms were used in the TMDL, such as "air deposition". EPA reviewed numerous regional and national PCB studies, including: Mittermeier, 2003; atmospheric gas phase PCB concentration as predicted by Venier and Hites (2010); and the University of Minnesota and LimnoTech's 2009 Report.[6] As a result, EPA has concluded that the approaches and assumptions in the TMDL's methodology are compatible with the literature reviewed, and that including only waters for which air deposition is the primary source of PCBs in the TMDL (see Appendix A) is consistent with the methodology. The explanation given in the Introduction of this Decision Document in Section 1, further supports EPA's conclusion that it is reasonable that those waters not fitting this methodology and assumptions should be excluded from the TMDL. EPA has concluded that the development and submittal of the TMDL is consistent with the prioritization process contained in the 2012 Integrated Report.

2. Description of the Applicable Water Quality Standards and Numeric Water Quality Target

The TMDL submittal must include a description of the applicable State/Tribal water quality standard, including the designated use(s) of the waterbody, the applicable numeric or narrative water quality criterion, and the antidegradation policy (40 C.F.R. §130.7(c) (1)). EPA needs this information to review the loading capacity determination, and load and wasteload allocations, which are required by regulation.

The TMDL submittal must identify a numeric water quality target(s) – a quantitative value used to measure whether or not the applicable water quality standard is attained. Generally, the pollutant of concern and the numeric water quality target are, respectively, the chemical causing the impairment and the numeric criteria for that chemical (e.g., chromium) contained in the water quality standard (WQS). The TMDL expresses the relationship between any necessary reduction of the pollutant of concern and the attainment of the numeric water quality target. Occasionally, the pollutant of concern is different from the pollutant that is the subject of the numeric water quality target (e.g., when the pollutant of concern is phosphorus and the numeric water quality target is expressed as Dissolved Oxygen (DO) criteria). In such cases, the TMDL submittal should explain the linkage between the pollutant of concern and the chosen numeric water quality target.

6 University of Minnesota and LimnoTech, 2009.

Comment:

Designated Uses

At a minimum, all surface waters in Michigan are designated for warm water fishery, other indigenous aquatic life and wildlife, and fish consumption. The waters covered by the Michigan PCB TMDL are impaired for either the "other indigenous aquatic life and wildlife" designated use and/or the fish consumption designated use. Michigan uses a numeric criterion for water column concentrations of PCBs to assess support of the "other indigenous aquatic life and wildlife" designated use. Michigan uses a fish tissue residue concentration value of PCBs as a target to interpret the attainment of Michigan's fish consumption use narrative standard.

Michigan supports its determination of a waterbody's achievement of its designated use by examining more than one type of data if available (i.e., water column and fish tissue concentrations). In order to determine if a use is supported in a given waterbody, each data type is evaluated independently to determine support for the designated use. Waters are listed as not supporting a given use if either or both data type indicates that the designated use is not supported. The TMDL states that "other indigenous aquatic life and wildlife" and/or the fish consumption designated uses in Michigan surface waters are impaired due to PCBs and are addressed by the TMDL (Section 3.1.1 of the TMDL). Based on its review of the TMDL documentation and the MDEQ 2010 Section 303(d) Integrated Report approved by EPA on 8/31/2010, EPA agrees that the waters identified as covered by this TMDL are impaired by PCBs. EPA notes that the 2012 and 2014 MDEQ Integrated Reports (approved on 3/15/13 and 8/13/2014, respectively) also document these PCB impairments. Waters addressed by the TMDL are identified in Appendix A of this Decision Document.

Numeric Standards

Michigan's WQSs include ambient water column numeric criteria for PCBs. Water column concentrations are used to assess support of the "other indigenous aquatic life and wildlife" designated use. The WQSs for water column PCB concentration is 0.12 ng/L for the protection of wildlife (R323.1057 (4)).[7] The human cancer value (HCV) for the protection of human health is 0.026 ng/L (R323.1057 (4)).[8]

Narrative Standards

TMDL submittals must identify numeric water quality targets, which are quantitative values used to measure whether or not applicable WQSs are being attained. Michigan's WQSs do not contain a fish tissue numeric criterion. Michigan's narrative portion of R323.1057(1) states, "toxic substances shall not be present in the surface waters of the state at levels that are or may become injurious to the public health, safety, or welfare, plant and animal life, or the designated uses of the waters."

MDEQ determined the consumption of fish by humans and wildlife is the most significant route of human exposure (Section 2.1 of the TMDL). Research by EPA (EPA, 2011) and the Center for Disease Control (ATSDR, 2000) explains that PCB fish consumption is the primary route of exposure to the public. Michigan uses a fish tissue residue concentration value as a target to interpret the attainment of Michigan's fish consumption use narrative standard for the statewide PCB TMDL (Section 3.2 of the TMDL). Michigan considers the concentration of PCBs in the

7 Section 3.1 of the TMDL.

8 Ibid.

water column, and the presence of fish consumption advisories issued by the Michigan Department of Community Health (MDCH) when assessing the status of the fish consumption use (Section 3.1.1 of the TMDL). Data used by the MDCH to determine fish consumption advisories are also considered for the assessment of the fish consumption use.

Deriving a Numeric Target to Attain the Narrative Standard

In addition to meeting the numeric water column criteria, the Michigan Statewide PCB TMDL established a fish tissue residue PCB target value to meet its "injurious to public health" narrative standard. MDEQ used the presence of fish consumption advisories to justify the use of a fish tissue target to interpret this narrative standard based upon the state standard noting that the criteria used for setting a TMDL target may include human health, aquatic life, and wildlife criteria (EPA, 2011).

Michigan calculated a fish tissue residue value of 0.023 mg/kg (wet weight) in edible fish as a reasonable interpretation of the narrative standard R323.1057(1), using a Risk Associated Dose (RAD) of 0.000005 mg/kg/day of PCB, based on a human body weight of 70 kg (a toxicity endpoint), and fish consumption rate of 0.015 kg/d. A RAD is defined as a dose of a known or presumed carcinogenic substance, in mg/kg/day, that, over a lifetime of exposure, is estimated to be associated with a plausible upper bound incremental cancer risk equal to 1 in 100,000. These values were also used in the derivation of the numeric WQS of 0.026 ng/L that protects human health (human cancer value (HCV)). The fish tissue residual value process is also consistent with the MDCH Technical Report.[9]

To verify that a fish tissue residue value would also attain the water column criteria for PCBs, MDEQ calculated the water concentration that would correspond to the fish tissue residue value of 0.023 mg/kg. The trophic level 4 bioaccumulation factor of 1,086,000 liters/kg, that was used in the calculation of the numeric PCB water column criteria of 0.026 ng/L for the protection of human health, was used to estimate what the water column PCB concentration would be for a trophic level 4 fish with a tissue residue value of 0.023 mg/kg. The resulting PCB water column concentration value (0.021 ng/L) is lower than the numeric water column criteria (0.026 ng/L) for PCBs, demonstrating that a TMDL target based on the fish tissue residue value would be at least as protective as a target based on the numeric WQS.

EPA finds that the TMDL document submitted by MDEQ adequately identifies the WQSs that are impaired, and the TMDL target needed to attain both impaired designated uses of the WQSs. Michigan derived a fish tissue residual value target of ***0.023 mg/kg of PCB*** *to interpret the narrative standard of* "toxic substances shall not be present in the surface waters of the state at levels that are or may become injurious to the public health". *EPA has reviewed MDEQ's TMDL target calculations and finds that this TMDL target was correctly calculated and stringent enough to meet the WQSs. EPA finds that this numeric target is appropriate because this value is directly related to fish consumption, which is the primary pathway of PCBs affecting human health, and is directly related to loading of PCBs to the waterbodies. As discussed above, EPA also agrees with MDEQ that this target is consistent with the human health WQS of 0.026 ng/L. As noted above, the human health WQS of 0.026 ng/L is below the water column concentration of PCBs for the protection of wildlife (0.12ng/L). Attainment of the human health WQS will result in the attainment of the wildlife protection WQS.*

9 MDCH, 2012.

3. Loading Capacity - Linking Water Quality and Pollutant Sources

A TMDL must identify the loading capacity of a waterbody for the applicable pollutant. EPA regulations define loading capacity as the greatest amount of a pollutant that a water can receive without violating water quality standards (40 C.F.R. §130.2(f)).

The pollutant loadings may be expressed as either mass-per-time, toxicity or other appropriate measure (40 C.F.R. §130.2(i)). If the TMDL is expressed in terms other than a daily load, e.g., an annual load, the submittal should explain why it is appropriate to express the TMDL in the unit of measurement chosen. The TMDL submittal should describe the method used to establish the cause-and-effect relationship between the numeric target and the identified pollutant sources. In many instances, this method will be a water quality model.

The TMDL submittal should contain documentation supporting the TMDL analysis, including the basis for any assumptions; a discussion of strengths and weaknesses in the analytical process; and results from any water quality modeling. EPA needs this information to review the loading capacity determination, and load and wasteload allocations, which are required by regulation.

TMDLs must take into account critical conditions for stream flow, loading, and water quality parameters as part of the analysis of loading capacity. (40 C.F.R. §130.7(c)(1)). TMDLs should define applicable critical conditions and describe their approach to estimating both point and non-point source loadings under such critical conditions. In particular, the TMDL should discuss the approach used to compute and allocate non-point source loadings, e.g., meteorological conditions and land use distribution.

Comment:
Summary of Major Steps in Michigan's Statewide PCB TMDL Approach
A summary of the steps that MDEQ took to calculate the TMDL is presented below, followed by a detailed description of the steps. Table 2 of this Decision Document lists the subsections in the Decision Document, and their corresponding sections in the TMDL Document.

Table 2: Steps Taken to Calculate PCB TMDL as Discussed in TMDL Document and EPA Decision Document

Decision Document Section	TMDL Section	Title
3.1	4.1	Representing Atmospheric PCB Loading Using Gas Phase PCB Concentrations
3.2	4.2	Relating Atmospheric Loading to Fish Tissue Concentration (Principle of Proportionality)
3.3	4.3	Atmospheric PCB Concentrations (Regionalization)
	4.4	
3.4		Selection of Representative Fish Species
3.5	4.5	Derivation of Threshold Proportionality Constant
3.6	4.6	Required Reduction Percentage
3.7	6.1	Determining a Maximum Daily TMDL Expression

Section 4.0 of the TMDL describes how Michigan determined the PCB reductions that would be needed in the environment to reach the fish tissue target and meet the narrative standard. The TMDL focuses on waters that MDEQ determined were primarily impaired by atmospheric sources of PCBs based on the existing data and information. Therefore, MDEQ's approach linked the needed percent reduction in current atmospheric gas vapor concentrations (loadings) to the percent reduction needed in current fish tissue concentrations to reach the target concentration of PCBs in fish tissue.

As discussed in more detail in Section 3.4 of this Decision Document and in Sections 4.3 and 4.5.2 of the TMDL, MDEQ selected lake trout (*Salvelinus namaycush*) as the target species on which to base PCB reductions. The approach used by MDEQ was to base reductions in PCB concentrations in fish tissue on an appropriate level of protection. As discussed in more detail in Section 3.5 of this Decision Document and in Section 4.5.1 of the TMDL, MDEQ selected the 90th percentile fish tissue concentration level to set reductions in fish tissue concentrations. This means that after the reductions from the TMDL are reached, fish with tissue PCB concentrations less than or equal to the concentration found in fish at the 90^{th} percentile concentration level would be expected to attain WQS, i.e., not be injurious to public health if eaten. Waters with fish tissue PCB concentrations greater than the concentration found in fish at the ninetieth percentile concentration level are not included in this TMDL, and will be addressed through an individual TMDL or other means. Further detail on selecting the 90^{th} percentile is provided in Section 4.5.1 in the TMDL document.

Table 8 of the Decision Document presents a summary of the TMDL. The Loading Capacity (or TMDL) is 0.034 ng/m^3, which is expressed as the average daily maximum gas phase PCB concentration for the state (See Section 3.7 of this Decision Document for more details). MDEQ demonstrated that attaining this average daily maximum gas phase PCB concentration will result over time in a reduction of PCBs into waterbodies across the state, and eventually reducing fish tissue PCB concentrations to the target value in Table 3 below. The load allocation is expressed as a gas phase PCB concentration, and the Wasteload Allocation is expressed as pounds per day of PCB. To determine the load allocation value, a single area-weighted average annual current atmospheric gas phase PCB concentration was calculated to be 0.115 ng/m^3 for the entire state. This value was multiplied by the area-weighted threshold proportionality constant of 3.293 $(mg/kg)/(ng/m^3)$, which was derived based upon the 90th percentile current concentration values for fish lake trout). The result was a calculated current fish tissue PCB concentration of 0.378 mg/kg. The target fish tissue PCB concentration was then subtracted from the estimated current fish tissue concentration to determine that a 94 percent reduction in PCB fish tissue concentration would be needed to meet the fish tissue target of 0.023 mg/kg. Based upon the assumption (Section 3.2 of this Decision Document) that a given percent reduction in gas phase PCB concentration will result in an equivalent percent reduction in fish tissue PCB concentration, an estimate was made of the average atmospheric gas phase PCB concentration that would be needed to result in a 94% reduction in fish tissue. Further, a 94% reduction in an existing atmospheric gas phase concentration of 0.115 ng/m^3, would result in an annual average atmospheric gas phase concentration of 0.007 ng/m3. The calculation and results can be found in Section 3.6, Table 3 of this Decision Document.

Table 3: Calculation of Percent Reduction Required to Meet PCB Fish Tissue Target.

Gas Phase PCB Conc. Current Annual Statewide Average	Annual Average Atmospheric Gas Phase Conc.	Threshold Proportionality Constant (Multiplier)	Fish Tissue Current PCB Concentration (Standard Length Lake Trout)	Fish Tissue Target Concentration	Needed Percent Reduction in Current Fish Tissue Value (mg/kg) (0.378 -0.023) 0.378
0.115 ng/m^3	0.007 ng/m3	3.293 mg/kg (ng/m3)	0.378 mg/kg	0.023 mg/kg	94%

This calculation used the annual average temperatures in Equation 7 of the TMDL to define the annual average atmospheric gas phase PCB concentration across the state.

TMDLs require a daily expression of the maximum allowable loading that can be received by a waterbody and still meet designated uses. MDEQ defined a daily maximum gas phase PCB concentration by replacing the annual average temperature value in Equation 7 with the calculated daily maximum temperature for each EDU (Section 3.7 of this Decision Document). MDEQ established that the PCB Gas phase concentration varies with the Temperature on a daily basis and therefore is at a maximum when the daily Temperature is at its highest. Using the Ideal Gas Law, Michigan determined a daily expression representing the loading capacity (TMDL) as a daily maximum gas phase PCB concentration, based on the annual average daily maximum temperature, for each EDU concentration. From these values a single current area weighted daily maximum gas phase PCB concentration of 0.571 ng/m^3 was calculated for the state. A 94% reduction of this concentration results in the expression of the average daily maximum gas phase PCB concentration for the state of **0.034 ng/m^3** (the loading capacity).

3.1. Representing Atmospheric PCB Loading Using Gas Phase PCB Concentrations:
The Michigan Statewide PCB TMDL is focused on waters where the atmosphere is assumed to be the most significant source of PCBs. The Integrated Atmospheric Deposition Network (IADN) is a joint United States-Canadian monitoring network that provides atmospheric chemical concentration trends for the Great Lakes Basin. IADN data were combined with surface water program data to compute the total atmospheric transfer of chemicals of concern to Great Lakes surface waters. PCBs are transferred from the air to the water by the mechanisms of precipitation-related (wet) deposition, fine particle (dry) deposition and gas phase PCBs being absorbed into the water.

Because it was not feasible during TMDL development to directly measure the volume or amount of PCBs that are transferred from the atmosphere to the water column, MDEQ used the atmospheric gas phase concentration of PCBs to represent the volume or amount of transfer or "loading" of PCBs to surface waters from atmospheric sources. For the Decision Document this surrogate for loading will be referred to as "gas phase PCB concentration (loading)." MDEQ provided the following scientific and practical justifications for using gas phase PCB concentrations to represent net loading from the atmosphere to the water column.

- Studies using the IADN data, including studies in the Great Lakes (Venier and Hites, 2010; Blanchard *et al.*, 2008; and Buehler and Hites, 2002), showed that absorption of gas phase PCBs at the air/water interface is by far the largest contributor of PCBs

(>90-99%) to the water column from the atmosphere compared with wet and dry deposition in the Great Lakes region. These studies note that the wet and dry deposition loadings are approaching non-detect values.

- The gas phase concentration governs wet deposition (Günidi and Tasdemir, 2010).

- The portion of atmospheric PCB loadings to the water column from dry deposition is small compared with wet deposition (Blanchard *et al.*, 2008, and Buehler and Hites, 2002).

- The transfer of PCBs through absorption of gas phase PCBs at the air water interface acts similarly to the other types of deposition (Blanchard *et al.*, 2008, and Buehler and Hites, 2002).

MDEQ provides a detailed description of its use of the gas phase PCB concentrations to represent PCB loadings in Section 4.1 of the TMDL and Appendix C of the Decision Document.

EPA concludes that Michigan has provided a reasoned approach by using atmospheric gas phase PCB concentrations to represent atmospheric PCB loadings. EPA has reviewed several of the studies cited by MDEQ including Venier and Hites (2010), Blanchard et al., (2008) and Buehler and Hites (2002), as well as an additional study (Günidi and Tasdemir, 2010). EPA finds that it is reasonable for Michigan to assume that the predominance of absorption deposition of atmospheric gas phase PCBs over the Great Lakes would be applicable to inland waters, rivers and streams in the state of Michigan. Thus, MDEQ adequately demonstrates that the atmospheric gas phase concentration is the primary pathway for PCBs into the Michigan waterbodies covered by the TMDL, and that it is appropriate to assume that a given percent reduction in atmospheric gas phase PCB concentration will produce an equivalent percent reduction in atmospheric PCB loading to surface waters in the state of Michigan.

3.2. Relating Atmospheric Loading to Fish Tissue Concentration (Principle of Proportionality)

The second step in the approach for the Michigan Statewide PCB TMDL is found in Section 4.2 of the TMDL document. The relationship used by MDEQ in the TMDL document to make a quantitative link between atmospheric loading of PCBs and concentrations of PCBs in fish assumes a steady-state pollutant concentration in a waterbody that is linearly proportional to the PCB concentration in fish tissue. EPA believes this is a reasonable approach, as it is consistent with EPA technical document *The PCB TMDL Handbook* (EPA, 2011) for developing PCB TMDLs. The *Handbook* discusses the use of approaches such as assuming a proportional one-to-one relationship between PCB loadings and fish tissue, and using a bioaccumulation factor to calculate a water column value. In the Michigan Statewide PCB TMDL document, MDEQ assumes that a given amount of PCB loadings deposited in each waterbody results in a proportional concentration of PCBs in fish tissue. The proportionality model approach used for this TMDL uses existing observed fish tissue data and estimated gas phase PCB concentration (loading) to calculate a proportionality constant, α, as represented by Equation 3 in the TMDL Document:

a x Pollutant loading = [Pollutant concentration in water (or fish)] (Equation 3)

where:

a = Proportionality constant relating pollutant load to environmental (i.e., water or fish) concentration.

Rearranging the equation above (Equation 3, page 19 in the TMDL document) yields the proportionality constant to represent the relationship between atmospheric loadings of PCBs and fish tissue concentration:

a = Fish tissue concentration / Pollutant loading (Equation (4))

3.3. Determining Existing Atmospheric Gas Phase PCB Concentrations

After compiling the appropriate databases, one of the major data gaps identified by MDEQ was statewide gas phase PCB concentrations in the atmosphere over populated regions of Michigan. To address this data gap, MDEQ used the regression analysis developed by Venier and Hites (2010) (Section 4.3 of the TMDL) using data from the IADN network from across the Great Lakes region for several pollutants including PCBs. MDEQ used this regression analysis to analyze atmospheric gas phase PCB concentrations in several regions of the state. Samples were analyzed for the following locations and time periods:

- Brule River, Wisconsin (1996-2002)
- Eagle Harbor, Michigan (1990-2007)
- Sleeping Bear Dunes, Michigan (1992-2007)
- Chicago, Illinois (1996-2007)
- Cleveland, Ohio (2003-2007)
- Sturgeon Point, New York (1992-2007)

Venier and Hites (2010) converted observed gas-phase PCB concentrations to partial pressures using the Ideal Gas Law and the average atmospheric temperatures during the 24-hour sampling period measured at each site. They used the software package Minitab 15 to fit a linear regression to the logarithms of the atmospheric PCB partial pressures, resulting in Equation 6 in the TMDL. Equation 6 in the TMDL was used to estimate average atmospheric PCB concentrations for each EDU (Section 4.3 of the TMDL).

MDEQ used the area-weighted EDU values to calculate (Equation 7 in the TMDL) a statewide daily area-weighted average gas phase PCB concentration. EPA has reviewed the process used by MDEQ to determine the current daily average gas phase PCB concentration, and has concluded it is appropriate. Review of the PCB gas phase concentration data as well as the discussion in Venier and Hites (2010) clearly demonstrates the impacts that population have on PCB gas phase concentrations, and by using the EDU process to account for variations in biota (Higgins *et.al.*, 2005), MDEQ was able to account for the variability in PCB gas phase concentrations. The area-weighted average gas phase PCB concentration was calculated to be 0.115 ng/m^3 for the entire state.

The estimated 2010 average annual atmospheric PCB concentrations for each EDU (at the time of 2010 fish collection), are presented in Table 4 of the TMDL and additional detail on using Equation 7 to conduct that analysis are presented in Appendix C of the Decision Document.

Table 4: Estimated 2010 Annual Atmospheric PCB Concentrations (ng/m^3) Averaged by EDU (Table 4 from the Michigan Statewide PCB TMDL)

Ecological Drainage Unit (EDU)	Average Population Density (individuals per 25 km radius)	Average Total Gas Phase PCB Conc. (ng/m^3)	Area of EDU (miles^2)
Bayfield Peninsula and Uplands	<1,000	0.017	91.72
Chippewa-Black River	<1,000	0.017	0.45
Upper Illinois River	<1,000	0.017	7.49
Wisconsin River	<1,000	0.017	41.70
To Be Determined (includes Isle Royale and Drummond Island)	6,213	0.050	349.58
Western Upper Peninsula and Keweenaw Peninsula	11,199	0.052	3,295.46
Eastern Upper Peninsula	10,640	0.057	5,875.56
Central Upper Peninsula	19,117	0.062	6,707.16
Northern Lake Michigan, Lake Huron, and Straits of Mackinac	41,265	0.087	14,723.62
Western Lake Erie	43,243	0.102	457.01
Saginaw Bay	114,819	0.133	10,295.58
Southeast Lake Michigan	176,980	0.159	11,318.04
Southeast Michigan Interlobate and Lake Plain	830,371	0.278	4,121.54

When establishing reductions to meet the TMDL target in fish tissue, MDEQ explored a number of scenarios for regionalizing (or grouping) geographic areas together to see if they could be grouped by similar characteristics, as discussed in Section 4.4 of the TMDL document. MDEQ determined that there were not enough data to show a pattern in fish tissue concentrations in the selected target fish (trout) to group EDUs.

3.4. Selection of a Representative Fish Species

Michigan selected a representative fish species, and a target percentile of all fish, to determine the amount of PCB reductions that would be necessary for most fish throughout the state to meet water quality targets and return waters to designated uses (see Section 4.5 in the TMDL). MDEQ selected Lake Trout (*Salvelinus namaycush*) as the target species on which to base PCB reductions. MDEQ considered several criteria before selecting lake trout:

1) The species selected must have sufficient fish tissue samples to be considered representative.
2) The data must have been collected during a representative time period for the base year for the TMDL.
3) Only data 10 years old or less were included.

MDEQ also wanted to select a representative fish species that would ensure that a large majority of other fish species impacted predominantly by atmospheric PCB sources would also experience reductions sufficient to restore the fish consumption designated use. Lake trout is a level 4 predator, which means that by consuming numerous lower level predators, the species concentrates PCBs in its tissues as it increases in size, resulting in relatively high PCB concentrations as compared with other species that are smaller and lower on the food chain. A key assumption in the TMDL is that if reduction targets are set based upon lake trout, which have relatively higher PCB fish tissue concentrations, then the fish with lower concentrations would also be addressed by the reductions called for in the TMDL.

Additional factors considered in the selection of lake trout included having the second highest concentration of PCBs of all species reviewed, and that lake trout are a popular fish for human consumption. Fish collected from waterbodies known to have major legacy PCB sources and/or Great Lakes influence were not considered to be primarily influenced by air deposition, and were therefore excluded from the assessment. EPA concluded this was reasonable based upon data submitted by MDEQ in the TMDL as well as a review of the *Technical Support Document for a Polychlorinated Biphenyl Reference Dose (RfD) as a Basis for Fish Consumption Screening Values (FCSVs)* (MDCH, 2012), which discusses how contaminated sediments and other legacy sources of PCBs result in higher fish tissue concentrations of PCBs. By excluding fish impacted by these legacy sources, MDEQ addresses the impairments as a result of air deposition of PCBs, which is the focus of this TMDL effort (Section 1 *Problem Definition* of this Decision Document). Further, since the WQS for the protection of human health assumes that the majority (76%) of the fish consumed by humans are from trophic level 4, it was considered appropriate to apply the fish tissue target residue value to a trophic level 4 fish.

3.5. Deriving the Threshold Proportionality Constant

In the Michigan Statewide PCB TMDL, MDEQ used atmospheric gas phase PCB concentrations as a surrogate for atmospheric PCB loadings and then linked them to the resulting impairment caused by PCBs in fish tissue. MDEQ calculated a proportionality constant (defined as the PCB air concentration that results in a PCB fish tissue concentration for each water body with available lake trout fish tissue data (Section 4.5 of the TMDL). Section 4.5.3 of the TMDL describes how Michigan derived a Statewide "threshold" proportionality constant using existing fish tissue values for lake trout to be used to set the statewide percent reduction needed in PCB fish tissue concentrations to meet the fish tissue target. The threshold proportionality constant is defined as one that represents a specified upper bound/limit percentile of the observed distribution of proportionality constants for a target fish species, in this case lake trout.

A mean PCB concentration in fish tissue for each waterbody with available fish tissue data was calculated. Using the atmospheric gas-phase PCB concentration/loading and the mean fish tissue concentration for each waterbody, MDEQ used Equation 4 to calculate proportionality constants for all waterbodies in the State where PCB fish tissue data were available.

a = Fish tissue concentration / Pollutant loading (Equation 4)

Michigan selected a 90th percentile value to represent the threshold upper bound. As shown in Table 5 of the TMDL, the 90th percentile value of the calculated proportionality constants from observed lake trout data was 3.293 (mg/kg)/(ng/m^3). At this threshold, 90% of the waters in the state containing a top predator species with high bioaccumulation potential would be expected to attain the target goal of the TMDL (i.e., 0.023 mg/kg) after the required reductions are made. Those waters that exceed the 3.293 (mg/kg)/ (ng/m^3) proportionality constant (i.e., those over the 90th percentile) are considered outliers, and are excluded from the TMDL when identified. These waters likely have unknown legacy sources or respond differently to PCB air deposition, and therefore will require an individual TMDL to address the impairment (Section 4.5.1 of the TMDL). Examples of waters excluded from this TMDL include Kalamazoo River (Area of Concern under the Great Lakes Program) and the Au Sable River, Grand River, and the Shiawassee River (where fish tissue values exceed the 90th percentile). A more complete listing of outliers is found in a memo from Limnotech (Limnotech, May 10, 2013), and is included in this Decision Document as Appendix B.

EPA finds the State's selection of the 90th percentile to be reasonable because it is consistent with EPA's human health water quality criteria guidance.[10] *EPA's water quality criteria methodology was derived to protect the general population, and the methodology discusses the use of a combination of median values, mean values, and percentile estimates to guide development of criteria. The guidance also states that the assumptions are believed to be protective of the overall population and appropriate to meet the goals of the CWA. Similarly, EPA's Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (EPA, 2000) states: "The drinking water and fish intake values are 90th percentile estimates. EPA believes that these assumptions will be protective of a majority of the population and recommends them for state and tribal use."*

Michigan's analysis contained the following steps:

1) **Removing lake trout data collected prior to the year 2000:** Data collected prior to 2000 were judged to be non-representative of current conditions. MDEQ noted that PCB concentrations in fish were much higher prior to 2000, and have declined at a slower rate than pre-2000 (Table 1 of the TMDL). This is consistent with the data in Buehler and Hites (2002). In addition, the analysis methodology for PCBs changed around 2000 from Aroclors (industrial mixtures) to congeners (PCB chemical variants) (MDCH, 2012).
2) **Calculating the mean PCB fish tissue concentration for each water body with lake trout data:** To remove potential size-related biases in the calculation of mean fish tissue PCB concentrations, Michigan calculated the expected PCB concentration in a "standard length" fish in each water body consistent with the Technical Report for PCB FCA (MDCH, 2012) and the "Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory – Appendix V" (Great Lakes Sport Fish Advisory Task Force, 1993). Statistical regressions were then done between fish length and observed tissue concentrations for each water body. If water bodies showed a statistically significant ($\alpha = 0.01$) regression between tissue concentration and length, the mean PCB concentration was calculated

10 Office of Science and Technology, Office of Water, U.S. Environmental Protection Agency, Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health. October 2000. EPA-822-B-00-004.

using the site-specific regression and a fish length of 24 inches. This "standard length" was selected because it was the average length of all lake trout that were analyzed. For water bodies not showing a statistically significant regression, the mean concentration in a "standard length" fish was calculated as the average of all observed tissue concentration data for that water body. Resulting PCB concentrations in fish tissue for each water body are shown in Table 5 below.

3) **Calculating the proportionality constant associated with each water body with lake trout data:** Michigan calculated a proportionality constant using observed fish tissue concentration data, and using the atmospheric gas phase PCB concentration as a surrogate in place of an estimate of atmospheric load (discussed in Section 4.1 of the TMDL). The atmospheric gas phase PCB concentration was calculated using a regression (as shown in Equation 6 in the TMDL) corresponding to each lake trout sampling location specific to the year the lake trout were collected. A proportionality constant was generated for each water body by calculating the ratio of mean lake trout tissue PCB concentration to calculated atmospheric gas phase PCB concentrations (Table 5 of the TMDL).
4) **Calculating the statewide threshold proportionality constant:** The observed proportionality constants shown in Table 5 were assessed using Minitab statistical software. Maximum likelihood estimation, based on an assumption of a log-normal distribution, was used to calculate a 90th percentile value for the threshold proportionality constant. The 90th percentile threshold proportionality constant determined to represent a statewide value was calculated to be 3.293 (mg/kg)/ (ng/m^3).

Table 5: Lake Trout Data and Results for the Threshold Proportionality Constant Calculation.

Water Body Name	Location	Collection Date	# Fish	Mean Tissue PCB (mg/kg)	Proportionality Constant (mg/kg)/(ng/m3)	Average Atmospheric PCB at Time of Fish Sample Collection (ng/m3)
Crystal Lake	Benzie County	9/6/2000	15	0.17	1.75	0.096
Elk Lake	Grand Traverse/ Antrim County	4/11/2006	9	0.12	1.24	0.095
Glen Lake	Leelanau County	6/1/2009	9	0.14	1.55	0.088
Green Lake	Grand Traverse County	6/4/2003	10	0.12	1.25	0.098
North Lake Leelanau	Leelanau County	10/21/2003	12	0.27	2.78	0.098
Siskiwit Lake	Isle Royale	6/29/2002	10	0.04	0.64	0.060
Torch Lake	Antrim County	3/15/2009	11	0.36	4.02	0.089
90th percentile value					3.293	

3.6. Required Reduction Percentage.

The calculations in Section 4.6 of the TMDL demonstrate that a 94% reduction in statewide atmospheric PCB concentration is necessary to attain PCB levels that are protective of designated uses.

The overall reduction percentage required to meet TMDL targets was determined using the following steps:

1. Calculating the area-weighted average atmospheric gas phase PCB concentration in the state (see Section 3.2 of this Decision Document, Table 4 in the TMDL).[11]
2. Combining the atmospheric gas phase PCB concentration with the threshold proportionality constant to calculate fish tissue concentrations for existing conditions.
3. Determining the percentage by which existing tissue concentration would need to be reduced to attain the 0.023 mg/kg fish tissue target statewide

The area-weighted average atmospheric gas phase PCB concentration was calculated to be 0.115 ng/m^3 for the entire state. This value was multiplied by the area-weighted threshold proportionality constant of 3.293 (mg/kg)/ (ng/m^3)[12] to produce an estimated current fish tissue PCB concentration of 0.378 mg/kg. In order to meet the fish tissue target of 0.023 mg/kg, MDEQ calculated that a 94% reduction in fish tissue concentration would be required.

Once the required reduction was determined, MDEQ applied the assumption that a reduction in 2010 atmospheric gas phase PCB concentrations will result in a one-to-one reduction of fish tissue PCB concentrations. Therefore, since it is necessary to reduce existing tissue concentration by 94% to reach the fish tissue goal, the **estimated current average statewide atmospheric gas phase concentration of 0.115 ng/m^3 will need to be reduced by 94%, resulting in an allowable annual average atmospheric gas phase concentration of 0.007 ng/m3.**

EPA concludes that this PCB reduction calculation is reasonable. Section 2 of this Decision Document explains how MDEQ determined the current fish tissue PCB concentration and the fish tissue PCB concentration needed to attain WQS and meet the human health criteria as per 40 CFR 132. This requires a 94% reduction in fish tissue PCB concentrations. As noted in Section 3.3 of this Decision Document and Section 4.3 of the TMDL, MDEQ and EPA jointly reviewed studies from around the Great Lakes region. MDEQ utilized these studies to determine the atmospheric PCB gas concentration (0.115 ng/m^3). Based upon the assumption that a reduction in the atmospheric PCB gas concentration will result in a one-to-one reduction in fish tissue PCB concentrations (consistent with The PCB TMDL Handbook (EPA, 2011), MDEQ determined that a 94% reduction in atmospheric PCB gas concentration is required.

3.7. Daily Expression of the TMDL

Section 6.1 of the TMDL shows how a daily expression of the TMDL was derived. Atmospheric gas phase PCB concentrations are known to vary seasonally due to changes in air temperature. This can be seen in Equation 7 below. Using Equation 7, MDEQ calculated annual average atmospheric PCB concentrations across the state by using annual average temperatures for each EDU. EPA concurs this is a reasonable approach because PCBs accumulate in fish over time and fish tissue concentrations are not sensitive to seasonal variations in atmospheric PCB concentrations (Patterson *et. al.*, 2016). Because of the nature of bioaccumulation, the yearly average of all daily temperatures is a reasonable temperature value to use to calculate the overall

11 Statewide Michigan PCB Total Maximum Daily Load, MDEQ, August 2013, pgs.21-23.

12 based on the 90th percentile values

statewide gas vapor phase concentrations in the atmosphere that ultimately result in measureable fish tissue concentrations.

To meet the requirement that TMDLs be expressed as a daily value, MDEQ used Equation 7 to define the daily maximum concentration associated with the annual average, by replacing the daily average temperature value in the equation with the expected daily maximum temperature for each EDU. As temperature increases, the gas phase concentration of PCBs in the atmosphere also increases. MDEQ used the set of daily maximum temperatures in Equation 7 to express the upper boundary to the set of gas phase concentrations (loadings) that are observed throughout an average year. For a complete explanation of the daily expression calculation, see Section 6.1 of the TMDL.

$$\ln P = -14.1 + (-1.5 \times 10^{-4}\, t) + (-5.31(1000/T)) + 0.0744 \log^2(pop) \quad \text{(Equation 7)}$$

where T = Air Temperature (degrees Kelvin)
P = Atmospheric PCB Pressure (atm)
t = time Julian after January 1, 1990
pop = population within 25 kilometer (km) radius

The expected daily maximum temperature value for each EDU was used for the temperature variable. The following explanation is taken from Section 6.1 in the TMDL:

1. The mean extreme maximum temperature (annual) for each EDU was calculated from spatial data obtained from the NOAA National Climatic Data Center. This was done using the same equation but using the daily maximum temperature instead of the annual average temperature for each EDU.
2. The average population density (individuals per 25 kilometer radius) was calculated for each EDU using 2010 census data from the Michigan Department of Technology, Management and Budget Center for Shared Solutions and Technology Partnerships (Section 6.1 of the TMDL).
3. Atmospheric gas phase PCB concentrations for 2010 (based upon Venier and Hites, 2010) were calculated as partial pressures (in units of atmospheres) for each EDU, based on population density and average temperature, using Equation 7 (above).
4. Atmospheric PCBs partial pressures for each EDU were converted to concentration units (ng/m^3) using the ideal gas law, based on the maximum air temperature determined in Step 1.

The calculation in its entirety is presented in Appendix D of this Decision Document.

Table 4 of the TMDL summarizes the resulting daily maximum atmospheric gas phase PCB concentration for each EDU. A single area-weighted daily maximum atmospheric PCB concentration was calculated for the entire state by weighting the PCB concentration for each EDU, by the area of each EDU; this resulted in a concentration of 0.571 ng/m^3. Specification of daily maximum concentrations does not change the required load reduction percentage of 94%. The 94% required reduction was applied to meet TMDL targets, which resulted in the daily maximum atmospheric gas phase PCB concentration of 0.034 ng/m^3.

3.8. In-State Versus Out-of-State Loads/Sources

Section 4.3 of the TMDL describes how MDEQ divided the existing PCB concentrations into EDUs, and calculated a gas phase PCB concentration for each EDU. The most significant factor contributing to gas phase PCB concentrations is population, as noted in Vernier and Hites (2010a) and Buehler and Hites (2002). Urban areas (particularly highly urbanized areas such as Chicago and Cleveland) are more likely to have a greater concentration of PCB–containing sources such as older transformers, and illicit landfills (Melymuk *et al*, 2010). To determine the out-of-state portion of PCB load, MDEQ analyzed "wilderness areas". A wilderness area is defined as an area with less than a population of 12,500 per 25 km^2 [13] Several EDUs in the state meet the definition of wilderness areas (Section 6.1 of the TMDL). MDEQ assumed that the calculated values for atmospheric gas phase PCB concentrations for EDUs in these "wilderness" areas were from out-of-state sources, as there are no highly urbanized areas in the wilderness areas, and therefore PCBs present in the fish are due to volatilized PCBs migrating significant distances from any source (Vernier and Hites, 2010a; Melymuk *et al*, 2010). MDEQ then determined, therefore, that any gas phase PCB concentration levels in any EDU with a population above the wilderness level were from in-state sources (Section 6.1 of the TMDL).

The PCB contribution due to in-state sources was defined as the difference between the total atmospheric PCB concentration and the concentration attributed to out-of-state sources. MDEQ estimated an average statewide gas phase PCB contribution from in-state versus out-of-state atmospheric PCBs using a weighted average for each EDU by percentage of land area. MDEQ estimated that in-state sources make up 45% of the state's atmospheric PCB concentration, while out-of-state sources make up the remaining 55%, as shown in Table 6 below (detailed results by EDU are in Table 9 in the TMDL Document).

Table 6: Percent In-State Versus Out-of-State Sources of PCBs

Ecological Drainage Unit	Statewide atmospheric PCB Conc. (ng/m^3)	In-State Contribution to EDU PCB Conc. (ng/m^3)	Out-of-State Contribution to EDU PCB Conc. (ng/m^3)
Concentration (ng/m^3)	0.115	0.051	0.064
Percent of total Average PCB conc.	100%	45%	55%

3.9. Critical Condition

MDEQ noted that due to the nature of atmospheric gas phase PCB transfer to the water and subsequent concentration in fish, there is no specific critical condition for loading or water quality impacts. MDEQ explained that there may be certain water bodies and fish species that are more likely to bioaccumulate PCBs because of individual water chemistry characteristics, and the biochemistry of individual fish species. This aspect of critical conditions has been addressed in this TMDL by using a top predator fish species known to have high bioaccumulation potential.

EPA finds that the TMDL document submitted by MDEQ adequately identifies the loading capacities of PCBs due to air deposition across the state. As noted above in greater detail, MDEQ identified the gas phase PCB concentrations that represents the atmospheric loading into

13 PCB contribution due to out-of-state sources was defined for this TMDL by the PCB concentration predicted by Venier and Hites (2010a) for local populations associated with wilderness levels (12,500 people per 25 km radius) based on the definition of population density in wilderness areas worldwide (Mittermeier *et al.*, 2003).

waterbodies of the State. The State then related the atmospheric PCB loadings to fish tissue concentrations, and thereby showed how reductions in PCB loadings will result in reductions in fish tissue concentrations. MDEQ also documented the reductions needed in PCB loadings in the atmosphere, and thus to water, to attain the TMDL target for fish tissue concentration, as well as the loading capacity of PCBs, expressed as the average daily maximum gas phase PCB concentration for the state of ***0.034 ng/m^3****. MDEQ used data from the IADN network, as well as numerous other sources as noted above to determine the needed reductions and allocations.*

4. Load Allocations (LAs)

EPA regulations require that a TMDL include LAs, which identify the portion of the loading capacity attributed to existing and future non-point sources and to natural background. Load allocations may range from reasonably accurate estimates to gross allotments (40 C.F.R. §130.2(g)). Where possible, load allocations should be described separately for natural background and non-point sources.

Comment:
The LA is discussed in Section 6.1 of the TMDL document. Section 3 of this Decision Document describes how MDEQ identified nonpoint sources as the largest contributors of PCBs to surface waters, and further specified that PCBs transfer from the atmosphere to surface waters through gas vapor exchange as a predominant source. As a result, the focus of the Total Maximum Daily Load is on reductions to the atmospheric loading, which is reflected in the LA.

The TMDL analysis contained in Section 4.1-4.6 of MDEQ's submittal (and discussed in Sections 3.1-3.6 of this Decision Document) determined that the current average maximum daily load of PCBs from the air as represented by the current daily maximum gas vapor concentration of 0.571 ng/m^3 must be reduced by 94%, which results in a LA to non-NPDES sources of 0.034 ng/m^3 atmospheric gas phase concentration.

MDEQ explains in Section 6.1 in the TMDL (discussed in Section 3.10 of this Decision Document) that PCBs are from both in-state and out-of-state sources. MDEQ made an estimate of the PCB contributions from in-state versus out-of-state sources to Michigan waters to determine the proportion of the PCB load for which the State has regulatory authority. MDEQ noted that reductions will be needed from out-of-state sources in order for Michigan waters to attain WQSs and designated uses. MDEQ estimated that in-state sources make up 45 percent of the State's atmospheric PCB concentration, while out-of-state sources make up the remaining 55 percent. The reason for the estimate given by MDEQ is to better understand which implementation activities might be needed to address in-State PCB sources where possible. EPA notes that this does not change the 94% reduction of sources required by the TMDL, and that all TMDL reductions are assigned to the LA.

EPA finds that the TMDL document submitted by MDEQ adequately identifies the load allocation of PCBs due to air deposition across the State. MDEQ explained how the load allocation was calculated from the atmospheric gas phase concentration. MDEQ also calculated the estimated portion of PCB loading generated from out-of-state sources versus in-state sources. As noted above in Section 3 of this Decision document, MDEQ reviewed the gas phase data from across the state, to determine if it was feasible to allocate loads based upon regional

changes in PCB values. The State concluded, and EPA concurs, that while there are some regional differences in air PCB values, there are insufficient data to relate those differences to fish tissue concentrations. Section 3.3 of this Decision Document explains that while studies (i.e., Vernier and Hites, 2010b) demonstrate the impacts of population on PCB gas phase concentrations, there is insufficient data to determine a regional pattern for PCB fish tissue concentrations. As a result, the State determined, and EPA agrees, that a state-wide load allocation is appropriate, based upon the available data.

5. Wasteload Allocations (WLAs)

EPA regulations require that a TMDL include WLAs, which identify the portion of the loading capacity allocated to individual existing and future point source(s) (40 C.F.R. §130.2(h), 40 C.F.R. §130.2(i)). In some cases, WLAs may cover more than one discharger, e.g., if the source is contained within a general permit. The individual WLAs may take the form of uniform percentage reductions or individual mass based limitations for dischargers where it can be shown that this solution meets WQSs and does not result in localized impairments.

Comment:
MDEQ discusses the waste load allocations in Section 5 of the TMDL. MDEQ identifies PCB loads for point sources regulated under the Clean Water Act. These sources are federally regulated under the National Pollutant Discharge Elimination System (NPDES) permit program. For the purposes of the PCB TMDL, these sources consist of regulated wastewater and stormwater discharges. MDEQ also groups other sources under the WLA Section of the TMDL (i.e., industrial, landfills, and Superfund sites) for the purpose of implementation planning. Only the sources identified in Table 7 below are part of EPA's approval of WLAs in this Decision Document.

NPDES Municipal Separate Storm Sewer System (MS4)
Available data from NPDES regulated stormwater discharges were not sufficient at the time of MDEQ's submittal of the TMDL to estimate PCB loadings from stormwater or for specific outfalls. As there was little to no data regarding PCBs in stormwater in Michigan, MDEQ opted to target the source of the PCBs, rather than developing stormwater WLAs based upon very limited to no data. MDEQ determined that PCBs in municipal stormwater areas derive primarily from atmospheric deposition, which is accounted for in the LA of the TMDL (Section 1 of this Decision Document). Sources that could contribute PCBs directly to stormwater are to be addressed with controls to reduce atmospheric loading as necessary to meet the LA. Actions to control any potential solids and to comply with state municipal and industrial NPDES stormwater permits are also expected to contribute to reductions.

As referenced above, subsequent to MDEQ's submittal of its statewide PCB TMDL, a TMDL-related study for Spokane, Washington containing data and information about PCB levels in stormwater, and sources contributing to those loadings, has become available. This data and information has been incorporated into the proposed Illinois Lake Michigan Toxics TMDL, which was submitted to EPA for final review on April 25, 2017 (IEPA TMDL website, 2017). In particular, the Illinois-proposed TMDL has identified approaches the Illinois Environmental Protection Agency intends to pursue with MS4s and others to address sources of PCBs such as certain caulks, paints, pigments and dyes, etc. that may contribute to urban stormwater loading.

EPA will share this information with MDEQ and recommend MDEQ develop an approach to specifically address these sources. As also discussed above, however, review of data from the City of Spokane indicates that even if the stormwater PCB levels in Michigan were similar to those in Spokane, the amounts are estimated to be a relatively small source compared to atmospheric loading as identified in this TMDL, and would not significantly affect the reductions needed from air deposition to meet the fish consumption designated use. As additional data regarding PCBs becomes available, the TMDL can be revised as appropriate to allow a revision of the WLAs.

NPDES Individual Facility Permits

Table 7 below presents 4 WLAs that were calculated for facilities that discharge to an inland water body and have PCB water quality-based effluent limits (WQBELs) in their NPDES permits (Section 6.2 of the TMDL). Point sources that have been issued effluent limitations by MDEQ within their NPDES permits were given WLAs (Section 6.2 of the TMDL) based on concentrations equal to the numeric water column criteria for PCBs (0.026 ng/L). The impact of these point sources is orders of magnitude less than the contributions from the nonpoint sources. Therefore, the PCB reductions required to achieve the TMDL target depend primarily upon the LA reductions.

The WLA for each facility listed in Table 7 below is equal to the permitted PCB effluent concentration, which is the human health-based numeric water quality criteria (0.026 ng/L), multiplied by the facility's design flow as authorized by its NPDES permit. The total aggregate WLA for these four facilities is 1.19E-06 lbs/day.

MDEQ also identified several sites where Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) remediation is on-going. Substantive Requirement Documents (SRDs) are issued by the State of Michigan to Superfund sites that have current on-site remediation and are exempt from obtaining NPDES permits under Section 121(e) of CERCLA. MDEQ issues the SRDs to provide necessary surface water protection for on-site Superfund site cleanup. The TMDL submittal accounts for these loads under the Wasteload Allocation of the TMDLs. MDEQ allocated a total of 1.48E-06 lbs/day for NPDES and SRD permitted facilities.

Table 7: Waste Load Allocations for NPDES and SRD PCB-Permitted Facilities

Designated Name	NPDES Permit No.	Authorized flow (MGD)	Load (lbs/day)
G and H LF PRP Group	MIU990012	0.558	1.21E-07
GM – Pontiac SW Facility	MI0058908	1.44	3.10E-07
GM – Powertrain Flint North	MI0001597	0.022	4.80E-09
Liquid Disposal, Inc. – SF site	MIU990003	0.05	1.10E-09
Organic Chemicals – SF site	MIU990002	0.3	5.00E-08
Rose Twp. Settling Defendant – SF site	MIU990014	0.65	1.10E-7
Saginaw Twp.-Center Rd LF	MI0054739	0.024	5.20E-09
U.S. EPA –Shiawassee River SF site	MIU990023	0.013	2.80-E09
Wayne Disposal Inc. LF	MI0056413	4	8.70E-07
		Total:	**1.48E-06**

EPA finds that the individual WLAs for the NPDES – permitted facilities in the TMDL document submitted by MDEQ satisfy all requirements of this element.

6. Margin of Safety (MOS)

The statute and regulations require that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)). EPA's 1991 TMDL Guidance explains that the MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS must be described. If the MOS is explicit, the loading set aside for the MOS must be identified.

Comment:
The MOS for the Michigan Statewide PCB TMDL is implicit. It is accounted for by the fact that lake trout are relatively high in the food web (Level 4), and represent fish that are also relatively high in fish tissue PCB concentrations. Michigan used the 90th percentile PCB concentration to determine the reduction needed in the lake trout fish tissue concentration, which is a relatively high concentration of PCBs. The State reasoned that most fish (smaller fish or fish lower in the food chain) in the state will likely have a lower tissue PCB concentration, and that protecting standard length lake trout from PCB contamination will be protective of other fish species and consumers who eat them.

EPA finds that the TMDL document submitted by MDEQ adequately identifies the margin of safety for PCBs due to air deposition across the state. MDEQ explained how the MOS is implicit and based upon conservative assumptions used throughout the TMDL. MDEQ noted that using lake trout (a longer-lived top predator) would maximize the amount of PCB reduction necessary to attain the fish consumption designated use.

7. Seasonal Variation

The statute and regulations require that a TMDL be established with consideration of seasonal variations. The TMDL must describe the method chosen for including seasonal variations. (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)).

Comment:
Seasonal variation is accounted for by expressing the TMDL in terms of a fish tissue target. Seasonal PCB concentrations in the atmosphere and water column fluctuate along with atmospheric temperatures. However, PCBs accumulate in fish tissue over a period of years, so that the PCB concentrations in fish represent an integration of seasonal variation up to the time of sample collection. As noted in Rasmussen, *et al*, 1990, lake trout diet and the pelagic food chain are more important in determining PCB concentration than the direct bioconcentration from water to fish tissue. Variations in size, diet, and habitat, are expected to influence fish tissue concentrations more than seasonal variability. The Statewide threshold proportionality constant, which is calculated using the fish tissue PCB concentration data for lake trout, allows for the

variability in fish tissue concentrations, which is reflected in the identified percent reduction to reach the fish tissue target TMDL target.

EPA finds that the TMDL document submitted by MDEQ adequately accounts for seasonal variation for PCBs due to air deposition across the state. Studies show that seasonal variation of PCB loading is not as significant to PCBs in fish tissue as the longer-term food consumption.

8. Reasonable Assurances

When a TMDL is developed for waters impaired by point sources only, the issuance of a National Pollutant Discharge Elimination System (NPDES) permit(s) provides the reasonable assurance that the wasteload allocations contained in the TMDL will be achieved. This is because 40 C.F.R. 122.44(d)(1)(vii)(B) requires that effluent limits in permits be consistent with "the assumptions and requirements of any available wasteload allocation" in an approved TMDL.

When a TMDL is developed for waters impaired by both point and non-point sources, and the WLA is based on an assumption that non-point source load reductions will occur, EPA's 1991 TMDL Guidance states that the TMDL should provide reasonable assurances that non-point source control measures will achieve expected load reductions in order for the TMDL to be approvable. This information is necessary for EPA to determine that the TMDL, including the load and wasteload allocations, has been established at a level necessary to implement water quality standards.

EPA's August 1997 TMDL Guidance also directs Regions to work with States to achieve TMDL load allocations in waters impaired only by non-point sources

Comment:
The manufacture and use of PCBs in the United States were banned in the 1970s. Figure 2 in the TMDL provides a summary of monitoring data that showed a steady and steep decline in atmospheric concentration of PCBs in the Great Lakes region over the last several decades (Section 2.1.2 of the TMDL). The breakdown of PCBs in the environment occurs through interactions with chemicals such as ozone and microorganisms.[14] Section 7 of the TMDL Document (Reasonable Assurance and Implementation) cites a regression developed by Venier and Hites (2010a)[15] which shows that atmospheric PCBs in the Great Lakes Region are decreasing over time, with a half-life of approximately 12.5 years. Calculations showed that the TMDL reduction goal would be achieved in approximately 50 years if atmospheric concentrations maintain the historic rate of decline. It is unclear if the rate of decline will continue at the same pace, based upon studies of climate change (MacKay and Bentzen, 1997; Lamon *et al*, 2009; Lamon *et al*, 2012).

Michigan described actions in the Reasonable Assurance and Implementation Section of the TMDL that will contribute to reductions in PCB loads to meet the LA under this TMDL. As noted in Section 3.8 of this Decision Document, MDEQ determined that 55% of the atmospheric PCB load is from out-of-state sources. Actions similar to those described by MDEQ are expected

14 Faroon *et. al*, 2003.
15 See Appendix E of this Decision Document.

to be taken to address out-of-state sources, as many of the MDEQ regulatory controls on PCBs are based upon Federal requirements, and therefore these controls are national in scope. Section 7 of the TMDL summarizes state and Federal regulations and activities such as remediation of legacy sites, restriction of disposal of PCBs in regular landfills, and rules for transporting PCBs. MDEQ can reasonably anticipate that these actions will accelerate the rate of PCB reductions to reduce the level of PCBs in the atmosphere, and avoid release of existing PCBs to the environment.

Since the ban on PCBs, many activities have been undertaken under the auspices of overarching agreements between the United States and Canada to reduce Great Lakes toxics. The 1987 Great Lakes Water Quality Agreement contained a target of 0.1 mg/kg wet weight for fish tissue concentrations for all the Great Lakes (EPA, 2012). The Binational Toxics Strategy (BNTS) is a joint effort of the United States and Canada started in 1997 to address the effects of toxic pollutants in the Great Lakes basin through goal-setting and tracking to assess progress on reducing contamination (EPA and Environment Canada, 2009). PCBs were listed as Level 1 contaminants (chemicals that both countries had proof were dangerous) in the BNTS. Provisions in the Toxic Substances Control Act (TSCA) authorize EPA to control any substance determined to cause unreasonable risk to public health or the environment. TSCA includes, among other things, prohibitions on the manufacture, processing, and distribution in commerce of PCBs. Thus, TSCA controls existing PCBs from management to disposal in the United States. The current PCB regulations were published pursuant to TSCA and can be found at 40 C.F.R. Part 761. MDEQ reasoned in the TMDL that reductions will continue as the impacts of these programs will prevent releases of PCBs from inappropriate disposal and transport of PCBs in the environment. Detailed information on such programs can be found in Section 7 of the TMDL.

Great Lakes Legacy Act (GLLA), Areas of Concern (AOCs), and Great Lakes Initiative (GLRI) Plans I and II

In 2008, Congress signed the Great Lakes Legacy Act.[16] Sediment cleanup can reduce the overall PCBs that are available to circulate in the environment. In Specific cleanup efforts in or near the inland TMDL areas include:

- River Raisin - The River Raisin AOC begins at the portion of the river downstream from Dam No. 6 in the City of Monroe, extending one half mile out into Lake Erie and along the nearshore zone of Lake Erie for one mile north and south. EPA and MDEQ began a $17.3 million joint project in June of 2012 to remove contaminated sediment from the River.[17] The project has resulted in about 109,000 cubic yards of sediment contaminated with PCBs being removed. During the course of the dredging, another 2 acres of PCB-contaminated sediments at a concentration of 70,000 ppm were discovered and the project continued into 2015 to remove additional contaminated sediments.[18] In the Fall of 2016, Cameron Davis, EPA Region 5, confirmed that all cleanup and restoration work prescribed under the Great Lakes Restoration Initiative has been completed, and as of the writing of this Decision Document, the work to remove the site from the binational list of

16 EPA Great Lakes Legacy Act website.

17 EPA, 2012a.

18 Conversation with Scott Czeniewski, GLNPO, EPA, September 11, 2014.

AOCs under the U.S.-Canadian Great Lakes Water Quality Agreement was to be finished in the Fall of 2016. Environmental monitoring will continue at the site. EPA provided more than $27 million in GLRI funding to restore the River Raisin AOC, and leveraged an additional $18 million in state and private funding for AOC work. The federal, state, local, and private partnerships on GLRI projects have remediated over 150,000 cubic yards of contaminated sediment, restored over 300 acres of aquatic habitat, and opened up an additional 23 miles of the River Raisin to fish migration and spawning.[19]

- Muskegon Lake - This 4,149 acre inland coastal lake is located in Muskegon County, Michigan along the east shoreline of Lake Michigan. An AOC includes the entire lake, with the lake being separated from Lake Michigan by sand dunes. Ruddiman Creek flows into the Muskegon River which flows through Muskegon Lake before emptying into Lake Michigan. The immediate inland area is primarily residential and industrial, with chemical and petrochemical companies, foundries, a pulp and paper mill, and other industries located on the lake or within its immediate watershed. In 2006, a $13.5 million dredging and cleanup project for Ruddiman Creek and Ruddiman Pond finished on schedule and resulted in the removal of 320 pounds of PCBs.

- Trenton Channel/Riverview - EPA and its partners have completed a feasibility study for cleaning up contaminated sediment in the Upper Trenton Channel of the Detroit River as part of the GLLA. This study reviewed and evaluated cleanup options to manage around 240,000 cubic yards of contaminated sediment. The public comment period for the proposed cleanup plan ended on Feb. 15, 2014. The plan is being updated.

The GLRI Task Force has more than 16 participating Federal departments and agencies.[20] Under the GLRI Action Plan (2010) cleanup of legacy sources of toxics continues to be a priority for funding. A goal of the Action Plan was to delist the six AOCs in Michigan[21] by 2014. The GLRI Action Plan II covering 2015-2019 was issued in September 2014 and continues this work towards the goal of restoring and protecting the Great Lakes. Cleaning up AOCs continues to be one of the 4 major focus areas of the GLRI II. Under GLRI Action Plan II, federal agencies and their partners will continue to remediate and restore Areas of Concern. Federal agencies will implement critical management actions in all of the remaining AOCs and will complete all management actions required to delist Muskegon Lake, Detroit River, Rouge River and River Raisin. Remediation and restoration in these Areas of Concern will include dredging contaminated sediment which will lessen the overall amount of PCBs available in the environment available as sources to contribute to airborne PCB concentrations.

Cleanup of Legacy Sources Under CERCLA

Under CERCLA's "Superfund," funding and mandatory clean ups of uncontrolled or abandoned hazardous waste sites has resulted in plans to remediate priority sites. Michigan has 86 sites on the list and many of these sites contain PCBs.[22] As noted above, PCB cleanups can reduce the overall PCBs that are available to circulate in the environment.

---

19 www.dredgingtoday.com. Posted on September 20, 2016, accessed 3/3/17.

20 http://greatlakesrestoration.us/priorities.html

21 Ibid.

22 See http://www.michigan.gov /region5superfund/npl/michigan/index.html

Restrictions on Landfill Disposal and Transport of PCBs
Volatilization of PCBs from Michigan landfills can contribute to the local atmospheric PCB concentrations (Breivik *et al.*, 2002). The Michigan Natural Resources Protection Act (NREPA), Part 115- Solid Waste Management, was amended in 2004 (Public Act 34) to prohibit PCBs from being delivered to or disposed of in a landfill.[23] Only regulated landfills can still receive PCBs.

Leakage and/or illegal dumping of PCB-contaminated liquid waste, and subsequent volatilization, can also be sources of PCBs to Michigan's atmosphere according to the Agency for Toxic Substances and Disease Registry (ATSDR, 2001). Michigan regulations now require the use of uniform hazardous waste manifests for all regulated shipments of PCB waste as required in Part 147, PCB Disposal, of the NREPA as per the current Operational Memos 121-4 and 147-1.24.

In this TMDL, the volatilization and subsequent air deposition of such sources of PCBs is addressed in the TMDL calculations. EPA recognizes that additional monitoring may be needed to further determine the impact of landfills on the PCB loads. The TMDL may be revised as new data is submitted.

EPA finds that the TMDL document submitted by MDEQ adequately identifies the reasonable assurances needed to address PCB reductions due to air deposition across the state. The reasonable assurances noted by MDEQ focus on source reductions, as control of PCBs once in the atmosphere is virtually impossible. In Section 7.2 of the TMDL, MDEQ has identified a mix of controls for specific sources (Superfund sites, AOCs, etc.) to reduce the PCBs that are available for volatilization from landfills, leakage and/or illegal dumping of PCB-contaminated waste during transport and proper disposal of PCB-containing oils and equipment (such as construction debris) and subsequent air deposition. Wide-ranging controls include the BNTS, and TSCA controls including, among other things, prohibitions on the manufacture, processing, and distribution in commerce of PCBs. Thus, TSCA regulates PCBs from manufacture to disposal in the United States. Additional information and best practices are being developed under other studies and efforts simultaneously with this TMDL Review and Decision Document. This information will be shared with MDEQ as they are developed to enhance existing actions in Michigan. As noted above, PCB gas phase levels have dropped significantly since the prohibition in 1977. EPA agrees it is reasonable that these efforts will result in the continued reduction of PCBs.

9. Monitoring Plan to Track TMDL Effectiveness

EPA's 1991 document, *Guidance for Water Quality-Based Decisions: The TMDL Process* (EPA 440/4-91-001), recommends a monitoring plan to track the effectiveness of a TMDL, particularly when a TMDL involves both point and non-point sources, and the WLA is based on an assumption that non-point source load reductions will occur. Such a TMDL should provide assurances that non-point source controls will achieve expected load reductions and such a TMDL should include a monitoring plan that describes the additional data to be collected to

23 See http://www.michigan.gov/documents/deq/DEQ-WHMD-OpMemo_115-27_271593_7.pdf
24 See http://www.michigan.gov/documents/deq/deq-whm-hwp-uniform-manifestrequirements_213003_7

determine if the load reductions provided for in the TMDL are occurring and leading to attainment of water quality standards.

Comment:
Michigan has a number of monitoring programs that support the post-TMDL monitoring goals. Michigan recommended that fish tissue samples collected by state agencies be assessed for PCBs at the same frequency as its water quality trends monitoring.

The Fish Contaminant Monitoring program (FCMP) is part of MDEQ's Water Quality Monitoring Strategy. The contaminant data for the edible portion of fish are used by the MDCH to develop the Michigan Fish Advisory. Whole fish data are used to track contaminant trends and caged fish data are used to identify sources of pollutants and evaluate spatial trends of contaminant source concentrations. Fish are collected at 22 fixed sites in the state including lakes, streams and the Great Lakes. Michigan also collects fish samples at 20-30 sites across the state each year, based upon their monitoring protocols. Up to 600 fish are sampled per year (MDEQ, 2014). Both the MDEQ and the MDCH will generate data that can be used to evaluate TMDL effectiveness.

Michigan will continue to measure effluent PCBs for permitted facilities that have WQBELs for PCBs, to determine whether facilities are meeting their WQBELs. Caged fish studies may identify new point sources of PCBs for which WQBELs for PCBs need to be included in their permits.

The United States and Canada maintain the Great Lakes Integrated Atmospheric Data Network (IADN) Program. The Master Stations (and several satellite stations supplementing detail) on each of the 5 Great Lakes will provide spatially delineated data for wet and dry deposition of PCBs. The state will continue to review PCB concentrations measured at these stations to track whether the trends of decreasing PCB concentrations in the atmosphere continue.

MDEQ will continue to collect new fish tissue and water column data as part of its monitoring and assessment programs. These data are used as part of its assessment program for the Clean Water Act Integrated 303(d) and 305(b) Report on water quality status that is submitted to EPA every two years.

The situations below identify the possible outcomes for waters where new PCB monitoring results are available. The possible outcomes of the state's assessment of new fish tissue and/or water column data for any lake or river assessment unit are:

1. There is insufficient PCB fish tissue or water column data to determine the impairment status of the assessment unit, and the assessment unit is likely placed in Category 3 of Michigan's 303(d) Integrated Report (IR), consistent with the IR process.

2. The assessment unit is determined to have a fish tissue PCB concentration less than or equal to the fish tissue target concentration (0.023 mg/kg) or ambient water column PCB concentrations less than or equal to the water column target concentration (0.026 ng/l). These waters are likely unimpaired, and will be addressed as appropriate in the IR process.

3. Waters impaired (above the 0.023 mg/kg fish tissue target or the water column target criteria of 0.026 ng/l) and below the 0.378 mg/kg fish tissue maximum would be considered addressed by the TMDL. The TMDL can be revised and these waters can be placed in Appendix A (the list of waters covered by the TMDL) after public notice, and review and approval of the revision to the TMDL by EPA. The new waters included in Appendix A could be placed in Category 4a of Michigan's 303(d) IR (representing impaired waters addressed by an approved TMDL), consistent with the IR process.

4. Waters impaired above the 0.378 mg/kg fish tissue maximum or above the ambient water column PCB concentration of 0.43 ng/L[25] would not be considered to be addressed by the TMDL, and would need to be placed in Category 5 of Michigan's 303(d) IR as impaired, consistent with the IR process.

Upon consideration of new fish tissue PCB data and other relevant information, and after providing notification and appropriate analysis or documentation to EPA, the State may revise this TMDL during future integrated reporting cycles through revisions to Appendix A (the list of lake and river assessment units addressed by the TMDL) and appropriate public notice.

MDEQ does not anticipate reopening or revising the entire TMDL when adding newly-identified waters; only Appendix A and the corresponding data would likely be revised and open for public comments. In such case, the rest of the TMDL and its supporting documentation would remain as approved, and as documented in the TMDL Decision Document. MDEQ will identify the proposed TMDL revisions in the appropriate public notice, including any revisions to Appendix A (if needed). EPA notes that the final decision on any waterbody's impairment status is made during the 303(d) list review and approval process.

EPA finds that the TMDL document submitted by MDEQ adequately discusses the monitoring efforts to address PCB reductions due to air deposition across the state. Michigan has a well-developed FCMP to determine the extent of fish consumption impairments in the state. MDEQ and MDCH will continue to monitor fish tissue samples as part of the Michigan Fish Advisory effort. The IADN network monitors air and precipitation concentrations of several pollutants including PCBs in several sites across the Great Lakes region. MDEQ also discussed the process by which additional PCB-impaired waters will be identified and addressed by the TMDL.

10. Implementation

EPA policy encourages Regions to work in partnership with States/Tribes to achieve nonpoint source load allocations established for 303(d)-listed waters impaired by non-point sources. Regions may assist States/Tribes in developing implementation plans that include reasonable assurances that non-point source LAs established in TMDLs for waters impaired solely or primarily by non-point sources will in fact be achieved. In addition, EPA policy recognizes that

25 0.043 ng/L represents the maximum water column concentration that can be addressed through a 94% reduction.

other relevant watershed management processes may be used in the TMDL process. EPA is not required to and does not approve TMDL implementation plans.

Comment:
Section 7 of the Michigan DEQ Statewide PCB TMDL document addresses both the Implementation and Reasonable Assurance elements. Please refer to Section 8 of the Decision Document for a summary of PCB reduction activities in Michigan's TMDL submittal.

EPA reviews, but does not approve implementation plans.

11. Public Participation

EPA policy is that there should be full and meaningful public participation in the TMDL development process. The TMDL regulations require that each State/Tribe must subject calculations to establish TMDLs to public review consistent with its own continuing planning process (40 C.F.R. §130.7(c) (1) (ii)). In guidance, EPA has explained that final TMDLs submitted to EPA for review and approval should describe the State's/Tribe's public participation process, including a summary of significant comments and the State's/Tribe's responses to those comments. When EPA establishes a TMDL, EPA regulations require EPA to publish a notice seeking public comment (40 C.F.R. §130.7(d) (2)).

Provision of inadequate public participation may be a basis for disapproving a TMDL. If EPA determines that a State/Tribe has not provided adequate public participation, EPA may defer its approval action until adequate public participation has been provided for, either by the State/Tribe or by EPA.

Comment:
Appendix B of the TMDL document provides additional detail on the Public Notice for the TMDL. The draft TMDL report was available for public comment from January 14, 2013 to April 23, 2013. The original comment period was extended from February 19, 2013. MDEQ posted the draft report online at http://www.michigan.gov/deq/0,1607,7-135-3313_3686_3728---,00.html. The announcement regarding the availability of the document and public meeting notice was posted on the MDEQ public calendar on January 14, January 28, and extension of the Public Comment Period on the document was posted on February 11, 2013. Letters were sent to stakeholders on January 15, 2013. A public meeting was held February 6, 2013 to gather comments on the draft TMDL.

MDEQ received several comments and letters questioning the PCB TMDL (Appendix B of the TMDL). These comments raised questions on a number of topics, including implementation of the TMDL, impacts of Superfund/legacy sites, and the role of point sources in the PCB impairments. MDEQ provided a detailed response to these comments. The major issues are summarized below.

Several commenters asked about the overall goal of the TMDL, and how it would be implemented. MDEQ explained the goal of the TMDL is to determine the reductions necessary to meet the PCB WQS for lakes and streams in Michigan. MDEQ has concluded that developing the target reductions and quantifying the loads is a significant step in developing future activities

to reduce PCBs and will serve as a reference for on-going monitoring and implementation efforts. Two commenters asked questions about various implementation actions to address PCBs, including any accelerated phase-out of PCB-containing materials and the release of inadvertent PCBs during several manufacturing processes (paint, recycled paper, etc.). MDEQ noted that the TMDL did not specifically address individual sources; rather, the TMDL focuses on the air deposition from numerous sources. MDEQ explained that to control air deposition, the generation/release of PCBs from the individual sources will be addressed through numerous existing federal and State programs (see Section 8 above).

Commenters also raised questions about how Superfund PCB sites as well as PCB legacy sites were accounted for in the TMDL. Some of the Superfund sites have restricted vents as part of the remediation process, and concerns were raised about the potential release of PCBs into the atmosphere from these sites. Questions regarding the potential for PCBs to volatilize from formerly submerged sediments in dam-removal locations were also raised. MDEQ explained that although there are limited available data, volatilization from these sources is likely very limited and localized, and is not a significant source of PCBs statewide. EPA recently approved two Records of Decision and a Proposed Plan for three sites in the Kalamazoo River Superfund site. Review of these documents indicates that actions will be taken to reduce or eliminate volatilization of PCBs in the remediation activities (EPA, 2015a; EPA, 2015b). One commenter noted that two Superfund Sites were closed and were no longer discharging. MDEQ reviewed the information, and concurred. The two sites (Georgia-Pacific King Highway site, permit number MIU990018 and EPA-Plainwell Dam Superfund site, permit number MIU990028) were removed from Table 10 of the TMDL.

Comments were also raised about the contribution of PCBs from point sources in the state, from both wastewater facilities and stormwater discharges. Commenters wanted to clarify if point sources were significant sources, and if additional controls would be required. MDEQ noted that while point sources are a source of PCBs, their contribution is small, and no additional point source controls are needed, based upon the available data and information in Michigan (Section 5 of this Decision Document). MDEQ also explained that while certain types of stormwater are permitted under the NPDES program and therefore are considered point sources, the source of PCBs in the stormwater is due primarily to air deposition, and there is insufficient data at this time to determine the loading from regulated sources of stormwater. Regardless of the pathway (i.e. direct runoff or volatilization from local sources and adsorption/deposition), PCBs entering waterbodies will be addressed through actions to reduce sources contributing PCBs to the environment. EPA agrees with this explanation, as explained in Section 5 of this Decision Document). Michigan's finding is based on data available at the time the TMDL was written and TMDL amendments may occur based on new information.

EPA finds that the TMDL document submitted by MDEQ adequately documents the public participation needed to develop the TMDL, and that MDEQ appropriately addressed comments received from the public. The TMDL was available to the public for over 90 days, and public noticed across the state through letters to interested parties and on the MDEQ State Calendar. As noted above, several comments were received, and addressed appropriately by MDEQ.

12. Submittal Letter

A submittal letter should be included with the TMDL submittal, and should specify whether the TMDL is being submitted for a *technical review* or *final review and approval*. Each final TMDL submitted to EPA should be accompanied by a submittal letter that explicitly states that the submittal is a final TMDL submitted under Section 303(d) of the Clean Water Act for EPA review and approval. This clearly establishes the State's/Tribe's intent to submit, and EPA's duty to review, the TMDL under the statute. The submittal letter, whether for technical review or final review and approval, should contain such identifying information as the name and location of the waterbody, and the pollutant(s) of concern.

Comment:
EPA received the final Michigan Statewide PCB TMDL documents and submittal letter from MDEQ on August 29, 2013. The transmittal letter explicitly stated that enclosed was the final TMDL report for EPA final review and approval. This submittal contained the Michigan Statewide PCB TMDL which addresses other indigenous aquatic life and wildlife designated use and/or the fish consumption designated use impairments due to PCBs. The TMDL addresses impaired waters throughout the State of Michigan, as listed in Enclosure 1 of the TMDL and Appendix A of this Decision Document.

EPA finds that the submittal letter and the accompanying final TMDL submittal transmitted by MDEQ adequately identifies the waterbodies and the impairments in question (Appendix A of the TMDL).

13. Conclusion

After a full and complete review, EPA finds that the Michigan state-wide PCB TMDL report satisfies all of the elements of approvable TMDLs. This approval is for **2104** TMDLs. The approval addresses 88 AUIDs impaired for fish consumption designated use, 1106 AUIDs impaired for indigenous aquatic life and wildlife designated use, and 910 AUIDs impaired for both uses.

EPA's approval of these TMDLs extends to the water bodies that are identified in Appendix A of this Decision Document with the exception of any portions of the water bodies that are within Indian Country, as defined in 18 U.S.C. Section 1151. EPA is taking no action to approve or disapprove TMDLs for those waters at this time. EPA, or tribes with 303(d) TAS authority as appropriate, will retain responsibilities under the CWA Section 303(d) for those waters.

Pursuant to Executive Order 13175, *Consultation and Coordination with Indian Tribal Governments* and with *EPA Policy on Consultation and Coordination with Indian Tribes (May 2011),* EPA invited tribal consultation on its action to review Michigan's State-wide TMDL for PCBs. EPA explained that its policy is to consult on a government-to-government basis with Federally recognized tribal governments when EPA actions and decisions may affect tribal interests. EPA did not receive any requests by tribes for consultation.

Table 8: TMDL Summary Table

TMDL Components	Units	Statewide
Target Level and Reductions Factor		
Target Fish PCB Concentration (Fish Tissue Residue Value)	mg/kg	0.023
Existing PCB Concentration for Standard Length Lake Trout	mg/kg	0.378
Reduction Factor 94%		
PCB Load for Baseline Year 2010		
Point Source Load	lbs/day	1.48E-06
Maximum Daily Nonpoint Source Concentration	ng/m^3	0.571
Final TMDL	**ng/m^3**	**0.034**
Margin of Safety (MOS)	**Implicit**	
Waste Load Allocation (WLA)	**lbs/day**	**1.48E-06**
Load Allocation (LA) (Maximum Daily Concentration Used as a Surrogate)	**ng/m^3**	**0.034**
PCB LA for In-state and Out-of-State Deposition Sources		
In-State Contribution to LA		45%
Out-of-State Contribution to LA		55%
Necessary Reduction from Anthropogenic Emission Sources for both In-State and Out-of-State Contribution		94%

References

ATSDR. 2000. Public Health Statement for Polychlorinated Biphenyls (PCBs)

ATSDR. 2001. ToxFAQs™ for Polychlorinated Biphenyls (PCBs) http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=140&tid=26. Accessed April 2012.

Blanchard, P., *et al.* 2008. Atmospheric Deposition of Toxic Substances to the Great Lakes: IADN Results through 2005. Environment Canada and the United States Environmental Protection Agency. ISBN: 0-978-0-662-48287-1, Canada Catalogue No. En56-158/2005E, EPA Report No. EPA 905-R-08-001.

Breivik, K., A. Sweetman, J.M. Pacyna, and K.C. Jones. 2002. Towards a Global Historical Emission Inventory for Selected PCB Congeners - A Mass Balance Approach. *Science of the Total Environment.* 290, 199-224.

Buehler, S.S. and R.A. Hites. 2002. The Great Lakes Integrated Atmospheric Deposition Network. *Environmental Science and Technology.* 36: 354A-359A.

Cocca P., Mercury Maps, A Quantitative Spatial Link between Air Deposition and Fish Tissue (italic), September 2001, EPA-823-R-01-009

Dredging Today.com, 2016 River Raisin Cleanup Almost Completed, accessed 3/3/2018

Faroon, et al., 2003. Polychlorinated Biphenyls: Human Health Aspects. Concise International Chemical Assessment Document 55, World Health Organization

Great Lakes Sport Fish Advisory Task Force. 1993. Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory

Gundi and Tesmiir. 2010. Wet and Dry Deposition Fluxes of Polychlorinated Biphenyls (PCBs) in an Urban Area of Turkey. *Water, Air & Soil Pollution, Springer .com*

Higgins, *et al.* 2005. A Freshwater Classification Approach for Biodiversity Conservation Planning. *Conservation Biology.* 19:432-445.

Lamon *et al*, 2009. Modeling the Global Levels and Distribution of Polychlorinated Biphenyls in Air under a Climate Change Scenario. *Environ. Sci. Technol.,* v. 43, pp 58818-5824

Lamon *et al,* 2012. Modeling the Influence of Climate Change on the Mass Balance of Polychlorinated Biphenyls in the Adriatic Sea. *Chemosphere*, v. 87. pp 1045-1051

LimnoTech. 2011. Draft TMDL Support Document for PCBs in Lake Ontario. Prepared for: USEPA Region 2. http://www.dec.ny.gov/docs/water_pdf/lakeontariopcbtmdl.pdf.

MacKay and Bentzen. 1997. The role of the atmosphere in Great Lakes contamination *Atmospheric Environment*, Volume 31, Issue 23, December 1997, Pages 4045-4047

Mandalakis and Stephanou, 2007. Atmospheric concentration characteristics and gas–particle partitioning of PCBs in a rural area of eastern Germany. Environmental Pollution, v. 147, Issue 1, May 2007, Pages 211-221

Melymuk *et al*, 2010. Wet Deposition Loadings of Organic Contaminants to Lake Ontario: Assessing the influence of Precipitation from Urban and Rural Sites. *Atmospheric Environment*, v. 45, pp 5042-5049

MDCH. 2012. Technical Support Document for a Poly chlorinated Biphenyl Reference Dose (RfD) as a basis for consumption Screening Values (FCVSs)

MDEQ. 2014. Fish Contaminant Monitoring Program, A Summary of Edible Portion Sampling Effort and Analytical Results with Recommendations for Updates to the Michigan Department of Community Health Eat Safe Fish Guide. MI/DEQ/WRD-15/001.

Mittermeier, *et al.* 2003. Wilderness and Biodiversity Conservation. *Proceedings of the National Academy of Sciences of the United States of America.* 100(18): 10309-10313.

Patterson *et. al.* 2016. Contrasting PCB Bioaccumulation Patterns Among Lake Huron Lake Trout Reflect Basin-Specific Ecology; Environmental Toxicology and Chemistry, v. 35, pp 65-73

Rasmussen *et al.* 1990. Food Chain Structure in Ontario Lakes Determines PCB Levels in Lake Trout (*Salvelinus namaycush*) and other pelagic fish. *Canadian Journal of Fishery and Aquatic Sciences*, v. 47, pp. 2030-2038

Spokane, City of. 2014. City of Spokane Integrated Clean Water Plan.

Statistia, 2017, Retention/replacement time of the Great Lakes in the U.S. in 2004 (in years), https://www.statista.com/statistics/204184/retention-replacement-time-of-the-largest-lakes-in-the-us/

Thompson, S, MacKay, D and MacLeod, M. 1999. A Modeling Strategy for Planning Virtual Elimination of Persistent toxic Chemicals from the Great Lakes: An Illustration of four Contaminates in Lake Ontario. J. Great Lakes Res. 25(4):814–827

USEPA, 1999. Human Health Risk Assessment (executive summary), Hudson River PCBs, Region 2

USEPA 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000), EPA-822-B-00-004

USEPA 2004. Results of the Lake Michigan Mass Balance Study: Polychlorinated Biphenyls and trans-Nonachlor Data Report, GLNPO

USEPA 2006. Results of the Lake Michigan Mass Balance Study: Polychlorinated Biphenyls, Modeling Report, GLNPO

USEPA. 2011. PCB TMDL Handbook EPA Report #841-R-11-006. http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/pcb_tmdl_handbook.pdf.

USEPA. 2012. Great Lakes Monitoring: Air Indicators, Atmospheric Deposition of Toxic Pollutants. http://www.epa.gov/glindicators/air/airb.html.

USEPA. 2012a. River Raisin Legacy Act Cleanup news release, https://www.epa.gov/river-raisin-aoc/river-raisin-legacy-act-cleanup

USEPA. 2015a Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site, Operable Unit 7-Area 1. Record of Decision, USEPA Region 5

USEPA. 2015b Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site, Operable Unit 7-Area 1. Record of Decision, USEPA Region 5

USEPA and Environment Canada. 2009. Great Lakes Binational Toxics Strategy, 2009 Biennial Report. http://www.epa.gov/bns/reports/2009/2009GLBTSrpt.pdf.

University of Minnesota and Limnotech, 2009. Development Of A Multi-Media Great Lakes Basin Model For Screening Chemicals Of Emerging Concern - GLMOD.

Venier, M.A. and R.A. Hites. 2010a. Time Trend Analysis of Atmospheric POPs Concentrations in the Great Lakes Region Since 1990. *Environmental Science and Technology*. 44: 8050-8055.

Venier, M.A. and R.A. Hites. 2010b. Regression Model of Partial Pressures of PCBs, PAHs, and Organochlorine Pesticides in the Great Lakes' Atmosphere. *Environmental Science and Technology*, v. 44, pp 618-623

Wethington and Hornbuckle. 2005. Milwaukee, WI as a Source of Atmospheric PCBs to Lake Michigan. *Environmental Science and Technology*, v. 39, pp. 57-63

Appendix A

List of Waters Included in TMDL

Page intentionally left blank

Appendix B

Waters Considered for the TMDL but Excluded for not Meeting Fish Tissue Target Concentrations After Atmospheric Reductions

Table A-1. Legacy PCB Sites

Site Name	Type of Contaminated Site
Allied Paper	Superfund
Clinton River	AOC
Detroit River	AOC
Manistique River	AOC
Menominee River	AOC
Muskegon Lake	AOC
River Raisin	AOC
Rouge River	AOC
Saginaw River & Bay	AOC
Shiawassee River	Superfund
St. Clair River	AOC
St. Marys River	AOC
White Lake	AOC
Kalamazoo River	AOC/Superfund
Torch Lake	AOC/Superfund
Rockwell International	Superfund
Ten Mile Drain	Superfund

Table A-2. Sites excluded from PCB TMDL due to fish concentrations that will not meet the target

Water body name	Location (FCMP sampling site)
Au Sable River	Oscoda
Boyne River	Charlevoix County
Cheboyganing Creek	Saginaw County
Clinton River	Macomb County above I-94 overpass
Clinton River	Macomb County, Mt. Clemens
Clinton River	Ryan Road, Utica
Erickson Power Plant Pond	Eaton County
Escanaba River	Escanaba, river mouth
Grand River	Kent County, below Grand Rapids
Grand River	Portland Impoundment
Kent Lake	Oakland County
Manistique River	d/s Manistique Papers Dam
Manistique River	Manistique, river mouth
Menominee River	Menominee, river mouth
Muskegon Lake	Muskegon County
Muskegon River	Muskegon, river mouth
Platte Lake	Benzie County
Plum Creek	Monroe
Rabbit River	d/s Hamilton Dam
Raisin River	Monroe, below Winchester Bridge
Rouge River	Below M-153
Rouge River	Dearborn, river mouth
Rouge River	Wayne County, above turning basin
Rouge River	Wayne County, below Jefferson Ave
Rouge River, Lower Branch	Wayne County, Gulley Road
Rouge River, Middle Branch	Newburgh Lake
Rouge River, Middle Branch	u/s Nankin Dam
Saginaw River	Bay County, LaFayette
Shiawassee River	Saginaw County below Chesaning
Shiawassee River	Shiawassee County, Byron Road
Shiawassee River	Shiawassee County, New Lothrup Road
Shiawassee River, South Branch	Livingston County, Bowen Road
Shiawassee River, South Branch	Livingston County, Oak Grove Road
St. Joseph River	Benton Harbor, river mouth
St. Joseph River	Berrien Springs, below Dam
Thread Creek	Genesee County

Table A-3. Summary of All AUIDs Considered For Inclusion in the TMDL

Description	Count of AUIDs
Count of water body AUIDs impaired by PCBs based on the 2012 Integrated Report	2,330
Count of AUIDs excluded due to location in an AOC, location in a Superfund site, on the basis that they will not meet the TMDL target, or a combination of those factors	171
Count of Great Lakes AUIDs excluded	55
Total count of AUIDs covered under the PCB TMDL	2,104

Appendix C

Calculating Atmospheric PCB Concentrations

Calculating Atmospheric PCB Concentrations
(Estimations Across State EDUs -- from Section 4.3 of the TMDL)

Atmospheric PCB concentrations across Michigan were estimated based on the work described in Venier and Hites (2010b), who analyzed data for numerous persistent organic pollutants from the Integrated Atmospheric Data Network (IADN). Samples were analyzed for the following locations (Figure 7) and time periods:

- Brule River, Wisconsin (1996-2002)
- Eagle Harbor, Michigan (1990-2007)
- Sleeping Bear Dunes, Michigan (1992-2007)
- Chicago, Illinois (1996-2007)
- Cleveland, Ohio (2003-2007)
- Sturgeon Point, New York (1992-2007)

Venier and Hites (2010b) converted observed gas-phase PCB concentrations to partial pressures using the Ideal Gas Law and the average measured atmospheric temperatures within a 24-hour sampling period at each site. Minitab 15 software was used to fit a linear regression to the logarithms of the atmospheric PCB partial pressures, resulting in Equation 6 in the TMDL:

$$\ln P = -14.1 + (-1.5 \times 10^{-4}\, t) + (-5.31(1000/T)) + 0.0744 \log^2(pop) + (-0.0744(WS)) + (-0.0671 \cos(WD)) \quad \text{(Equation 6)}$$

where: P = Atmospheric (atm) PCB
t = time (Julian date after January 1, 1990)
T = air temperature (°K)
pop = population within 25 kilometer (km) radius
WS = wind speed (mph)
WD = wind direction (radians)

[Referenced from Decision Document Section 3.3]

Time, air temperature, and population density (Section 3.3 of this Decision Document) were the primary factors controlling atmospheric PCB concentration, so Equation 7 in the TMDL was used for the PCB TMDL:

$$\ln P = -14.1 + (-1.5 \times 10^{-4}\, t) + (-5.31(1000/T)) + 0.0744 \log^2(pop) \quad \text{(Equation 7)}$$

Equation 7 is designed for application at a specific location. To evaluate the spatial differences in atmospheric PCB concentrations across the state, Ecological Drainage Units (EDUs; Higgins et al., 2005) were used to aggregate areas of the state containing similar atmospheric concentrations of PCBs. They generally range in size from 1,000 to 10,000 km^2. The EDU boundaries align with but are not necessarily true watershed boundaries (Higgins *et al.*, 2005). The EDUs in Michigan are shown in Figure 8 of the TMDL.

Equation 7 was used to estimate average atmospheric PCB concentration for each EDU (Section 4.3 of the TMDL) as follows:

1. The annual average air temperature for each EDU was calculated from NOAA National Climatic Data Center.[26]
2. The average population density (individuals per 25 km radius) was calculated* for each EDU using 2010 census data from the Michigan Department of Technology, Management and Budget Center for Shared Solutions and Technology Partnerships.[27]
3. Atmospheric gas phase PCB concentrations for 2010 were calculated as partial pressures (in units of atmospheres) for each EDU, based on population density and average temperature, using Equation 7.
4. Atmospheric PCB partial pressures for each EDU were converted to concentration units (nanograms per cubic meter [ng/m3]) using an equation based on the Ideal Gas Law:

   Mass Concentration, ng/m^3 = (Partial Pressure, atm) * (average molecular weight) * (1012 ng/kg) * (1 $(kg/m^3)/(g/L)$ / (Henry's Law Constant 0.08205746 L atm K^{-1} mol^{-1}) / (Temperature °K as calculated in step 1 using T+273.15).

An average molecular weight of 288 g/mol was based on an assumed mixture of 65 percent Aroclor 1242 at 266.5 and 35 percent Aroclor 1254 at 328, from the reported measurements for the City of Chicago by Hu *et al.* (2010). The temperature in °K is associated with the partial pressure being converted.

*Geographic variability in atmospheric PCB concentrations was based on the multi-media Great Lakes basin model developed by the University of Minnesota and LimnoTech (2009) for the Great Lakes Commission. This model estimated emissions loadings of PCB congeners across the Great Lakes basin using an approach similar to the one developed by Hafner *et al* (2005) for polycyclic aromatic hydrocarbons. Existing data from nine stations in the Integrated IADN were used as the basis for the relationship between air concentration and population density. A log-log plot of annual average total PCB concentration data for 2001 versus population density (# within 25-km radius) was developed for the nine IADN stations (Figure 3). The trends in this plot suggest that 1) the air concentration increases non-linearly with increasing population and 2) a baseline concentration of approximately 100 pg/m^3 exists, which likely represents the dilution of more distant sources (Minnesota and LimnoTech, 2009).

26 See http://hurricane.ncdc.noaa.gov/cgibin/climaps/climaps.pl?directive=order_details&subrnum=&region=Lower%2048%20States&filename=temp0313

27 See http://www.michigan.gov/cgi/0,4548,7-158-54534---,00.html

Appendix D

Daily Expression of the TMDL

Daily Expression of the TMDL

From Page 37 of the TMDL

The observed and allowable atmospheric PCB concentrations are expressed as an annual average. The annual average appropriately reflects the long response time between changes in atmospheric concentration and changes in fish tissue concentrations. To comply with EPA guidance, the TMDLs are also expressed as daily maximum values in this TMDL, resulting in a value of .571. Atmospheric PCB concentrations are known to vary seasonally due to changes in air temperature. Equation 7 in the TMDL was first applied to define annual average atmospheric PCB concentrations across the state by using annual average temperatures for each EDU. The same equation can also be used to define the daily maximum concentration, by replacing the average annual temperature with the expected daily maximum temperature for each EDU as follows:

1. The mean extreme maximum temperature (annual) for each EDU was calculated from spatial data obtained from the NOAA National Climatic Data Center.

2. The average population density (individuals per 25 kilometer radius) was calculated for each EDU using 2010 census data from the Michigan Department of Technology, Management and Budget Center for Shared Solutions and Technology Partnerships.

3. Atmospheric gas phase PCB concentrations for 2010 were calculated as partial pressures (in units of atmospheres) for each EDU, based on population density and average temperature, using Equation 7. Atmospheric PCBs partial pressures for each EDU were converted to concentration units (ng/m3) based on the maximum air temperature determined in Step 1 using the following equation based on the Ideal Gas Law:

Mass Concentration, ng/m^3 = (Partial Pressure, atm) * (average molecular weight) * (1012 ng/kg) * (1 $[kg/m^3]/[g/L]$) / (Henry's Law Constant 0.08205746 L atm K^{-1} mol^{-1}) / (Temperature °K).

An average molecular weight of 288 g/mol was based on an assumed mixture of 65 percent Aroclor 1242 at 266.5 g/mol and 35 percent Aroclor 1254 at 328 g/mol, from the reported measurements for the city of Chicago by Hu *et al.* (2010). The temperature in °K was obtained as T + 273.15, where T is the temperature in °C associated with the partial pressure being converted.

Table 4 summarizes the resulting daily maximum atmospheric PCB concentration (and the average daily gas phase PCB concentration) for each EDU. A single area-weighted daily maximum atmospheric PCB concentration was calculated for the entire state by weighting the EDU-average PCB concentration by the area of each EDU; this resulted in a concentration of 0.571 ng/m^3. It is noted that this value is the daily maximum atmospheric PCB concentration that exactly corresponds with the annual average PCB concentration used as the basis for determining required load reductions. Specification of daily maximum concentrations in this manner does not change the required load reduction percentage of 94 percent. When the 94 percent required reduction is applied to meet TMDL targets, the average daily maximum atmospheric PCB concentration is 0.034 ng/m^3.

Table 4. Estimated 2010 Annual Atmospheric PCB Concentration (ng/m^3) Averaged by EDU

Ecological Drainage Unit (EDU)	Average Population Density (individuals per 25 km radius)	Average Total Gas Phase PCB Conc. (ng/m^3)	Daily Maximum Total Gas Phase PCB Conc. (ng/m^3)	Area of EDU ($miles^2$)
Bayfield Peninsula and Uplands	<1,000	0.017	0.259	91.72
Chippewa-Black River	<1,000	0.017	0.230	0.45
Upper Illinois River	<1,000	0.017	0.279	7.49
Wisconsin River	<1,000	0.017	0.230	41.70
To Be Determined (includes Isle Royale and Drummond Island)	6,213	0.050	0.246	349.58
Western Upper Peninsula and Keweenaw Peninsula	11,199	0.052	0.315	3,295.46
Eastern Upper Peninsula	10,640	0.057	0.284	5,875.56
Central Upper Peninsula	19,117	0.062	0.363	6,707.16
Northern Lake Michigan, Lake Huron, and Straits of Mackinac	41,265	0.087	0.453	14,723.62
Western Lake Erie	43,243	0.102	0.482	457.01
Saginaw Bay	114,819	0.133	0.636	10,295.58
Southeast Lake Michigan	176,980	0.159	0.739	11,318.04
Southeast Michigan Interlobate and Lake Plain	830,371	0.278	1.372	4,121.54

Appendix E

State Contribution to the TMDL

State Contribution to the TMDL

(See page 35 in TMDL Document)
The calculations in Section 4 demonstrated that a 94 percent reduction in statewide atmospheric PCB concentration is necessary to attain PCB levels that are protective of designated uses. Given an existing atmospheric gas phase concentration of 0.115 ng/m^3, a 94 percent reduction results in an allowable annual average concentration of 0.007 ng/m^3.

Michigan divided existing PCB concentrations into separate components corresponding to: (1) out-of-state sources; and (2) within-state sources. The separation of in-state and out-of-state sources was made using Equation 7 (Section 4.3 of the TMDL), which bases total atmospheric PCB concentration on local population. The PCB contribution due to out-of-state sources was defined for this TMDL by the PCB concentration predicted by Venier and Hites (2010a) for local populations associated with wilderness levels (12,500 people per 25 km radius) based on the definition of population density in wilderness areas worldwide (Mittermeier *et al.*, 2003).

Lastly, an average statewide contribution from in-state versus out-of-state atmospheric PCBs was estimated using a weighted average for each EDU by percentage of land area. In-state sources make up 45 percent of the state's atmospheric PCB concentration, while out-of-state sources make up the remaining 55 percent.

Table 9 (of the TMDL). Estimated average anthropogenic PCB concentrations by EDU.

Ecological Drainage Unit (EDU)	Average Population Density (individuals per 25 km radius)	Average Total PCB Conc. (ng/m^3)	Average In-State PCB Conc. (ng/m^3)	Average Out of State PCB Conc. (ng/m^3)
Bayfield Peninsula and Uplands	<1,000	0.017	-	0.017
Central Upper Peninsula	19,117	0.062	0.007	0.055
Chippewa-Black River	<1,000	0.017	-	0.017
Eastern Upper Peninsula	10,640	0.057	-	0.057
Northern Lake Michigan, Lake Huron, and Straits of Mackinac	41,265	0.087	0.025	0.062
Saginaw Bay	114,819	0.133	0.064	0.069
Southeast Lake Michigan	176,980	0.159	0.088	0.072
Southeast Michigan Interlobate and Lake Plain	830,371	0.278	0.207	0.072
Area including Isle	6,213	0.050	-	0.050

Royale and Drummond Island				
Upper Illinois River	<1,000	0.017	-	0.017
Western Lake Erie	43,243	0.102	0.030	0.072
Western Upper Peninsula and Keweenaw Peninsula	11,199	0.052	-	0.052
Wisconsin River	<1,000	0.017	-	0.017
Area-weighted Statewide Average		0.115	0.051	0.064

If the TMDL was designed solely to reduce in-state sources, the necessary reductions from these sources would be calculated using Equation 9:

> % reduction to in-state deposition = RF / (1 – % out-of-state contribution) (Equation 9)
> Where
> RF = Required reduction factor in overall concentration

Given a required reduction factor of 94 percent, and an out-of-state contribution of 55 percent, Equation 9 indicates that in-state sources would need to be reduced by 209 percent if no reductions were made to out-of-state sources. In-state reductions in PCB atmospheric deposition will not achieve the TMDL target alone. Therefore, this TMDL assumes that reductions from out-of-state sources will be consistent with those required for in-state sources (i.e., 94 percent reduction will be required for both in-state and out-of-state sources). The following explanation is reproduced from Section 6.1 in the TMDL, which defines the daily maximum concentration (presented in Section 3.3 of the Decision Document) by using the expected daily maximum temperature for each EDU.

The calculations in Section 4.3 of the TMDL demonstrated that a 94 percent reduction in statewide atmospheric PCB concentration is necessary to attain PCB levels that are protective of designated uses. Given an existing atmospheric gas phase concentration of 0.115 ng/m^3, a 94 percent reduction results in an allowable annual average concentration of 0.007 ng/m^3. In-state sources make up 45 percent of the state's atmospheric PCB concentration, while out-of-state sources make up the remaining 55 percent.

Appendix F
Calculations Referenced in Decision Document

Standard 24- inch Trout mean Concentration Conversion:
Lake trout PCB tissue concentration data from Michigan were compiled and analyzed to calculate a statewide threshold proportionality constant for use in developing required PCB load reductions. Data post-2000 for edible portions of fish tissue were available for seven water bodies and are located in Table 5 in the TMDL.

Data collected prior to 2000 were judged to be non-representative of current conditions because the PCB concentrations in fish were much higher prior to 2000, have since declined at a slower rate than pre-2000 (Table 1 in the TMDL), and because the analysis methodology for PCBs in fish changed in 2000 from reporting Total Aroclors (industrial mixtures) to Total Congeners.

Lake trout tissue PCB concentrations can vary with fish size. MDEQ addressed potential length-related biases in mean tissue PCB concentrations by calculating the PCB concentration in a "standard length" fish in each water body using statistical regressions between fish length and observed tissue concentrations for each water body. For water bodies showing a statistically significant (alpha =0.01) regression between tissue concentration and length, the mean PCB concentration in fish was estimated using the site-specific regression value and a fish length of 24 inches (the average length of all lake trout analyzed).

For water bodies not showing a statistically significant regression between tissue concentration and length, the mean concentration in a standard length fish was calculated as the average of all observed tissue concentration data for that water body. Resulting PCB concentrations in fish tissue for each water body are shown in Table 5 in the TMDL.

Proportionality constant associated with each water body:
Calculation of a proportionality constant requires an estimate of atmospheric load and observed fish tissue concentration data. Atmospheric gas phase PCB concentrations were used as a surrogate for atmospheric load in this TMDL (see Section 4.1 of the TMDL). A regression was applied to calculate an atmospheric PCB concentration corresponding to each lake trout sampling location specific to the year the lake trout were collected. A proportionality constant for each water body was generated by calculating the ratio of mean lake trout tissue PCB concentration to atmospheric gas phase PCB concentrations (Table 5 in the TMDL).

Statewide Threshold Proportionality Constant:
The observed proportionality constants shown in Table 5 in the TMDL were assessed using Minitab statistical software. Maximum likelihood estimation, as implemented in the Minitab program and based on an assumption of a log-normal distribution, was used to calculate a 90^{th} percentile value for the threshold proportionality constant. The 90th percentile threshold was 3.293 (mg/kg)/(ng/m3).